
Appendix A¹
***Data Collection Spreadsheets and Macros for
the Partnership for Safe Water***

Section 1	Background on the Data Collection Spreadsheets and Macros
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¹ Developed by Eric M. Bissonette, Technical Support Center, USEPA.

Section 1 - Background on the Data Collection Spreadsheets and Macros

Spreadsheets have been prepared to assist utility partners in collecting performance data. The performance data (raw, settled, and filtered turbidity) will be used by the utility as integral components of the Self-Assessment. Information from these spreadsheets will also form the basis of reports to the Partnership to help track the effectiveness of the Partnership activities.

The spreadsheets have been developed to capture turbidity data from raw water, sedimentation basin effluent and filter effluent, but can be used to manage repetitive data of any kind (e.g., particle counts in certain size ranges, turbidity data from an individual filter, chemical dosages and flows) from any point in the process for up to 365 days worth of data. Macros have been written to generate frequency distributions, on a monthly and annual basis, to help evaluate trends and summarize the large amounts of data. Graphics capabilities of the spreadsheets are also built in to automatically plot trend charts and frequency distributions. There are also capabilities for generating summaries of the data to report as background information or on an annual basis. Other data summaries within the capabilities of each spreadsheet software version could be generated as well. The spreadsheets accommodate up to six values per day or one value per day.

Interpretation of data from the performance assessment is addressed in Chapter 4 of this handbook. In general, turbidity fluctuations in raw water being propagated through the sedimentation basin and filter effluents could indicate inadequate process control or physical limitations in one or all of the major unit treatment processes. The trend charts and frequency distributions can indicate variability of turbidity and trends in performance. Individual filter turbidity or particle data can be examined to determine if individual filters are not performing up to expectations.

Each spreadsheet has memory requirements of 1 MB of RAM, of which 250 KB at minimum has been allocated as expanded or enhanced memory. Systems with computers incapable of allocating memory above 640 KB should restrict data entry to one turbidity value per day for six months

worth of data per spreadsheet. If memory constraints persist, memory management techniques specified for individual software versions should be utilized.

Execution of the spreadsheet macros to analyze data, generate trend graphs, and calculate monthly percentile distributions is straightforward. The following instructions for loading selected spreadsheets, entering data, activating macros, and printing output were, however, generated assuming that users have some familiarity with spreadsheet software packages. Specific instructions for entering data are discussed in Section 5. Macro execution for LOTUS 123 Release 2.4 spreadsheets is approximately 15 minutes on a 486 25 MHz computer for twelve months of data. The WINDOWS spreadsheet macros take four minutes to complete once activated.

The spreadsheets are designed such that upon macro execution the user may simply print the previously defined range containing the percentile tables and graphs and submit this as the baseline report (please see the attached example Performance Assessment Data Collection Spreadsheet Output). Users requiring assistance in data entry and macro execution should contact Eric Bissonette of USEPA/OGWDW Technical Support Division at (513) 569-7933 or e-mail requests for assistance to bissonette.eric@epamail.epa.gov.

Users are encouraged to continue to use the spreadsheets to collect and analyze data after the baseline collection effort has been completed. Simply copy the provided spreadsheet with a new filename and continue data entry as defined for each spreadsheet type. Continued long term use of the data management spreadsheets will assist users in the conduct of Phase III - the self-assessment/self-correction phase and Phase IV - the third party assessment/correction phase of the Partnership for Safe Water, as well as provide fundamental input to a plant process control testing program.

PLEASE NOTE: Never work from the diskette containing the master copy of the data collection spreadsheets. Follow instructions for copying the appropriate spreadsheet and files described in Section 3 and work from that copy.

Section 2 - Selecting the Spreadsheet and Macros for Your Applications

Spreadsheets with macros have been developed to execute in LOTUS 123 Release 2.4 for DOS and 5.0 for WINDOWS, EXCEL Release 4.0 and 5.0 for WINDOWS, and QUATTRO PRO Release 5.0 for WINDOWS software systems. The spreadsheets will accommodate data entry of a single value per day or up to six values per day. Files preceded by the letter "d" represent spreadsheets capable of accommodating one sample per day. Files preceded by the number "4" represent spreadsheets capable of accommodating six samples per day (a sample every four hours). Select the files corresponding to your application and data entry needs from the following table and proceed to Section 3.

Section 3 - Loading the Spreadsheet and Macros

The Spreadsheet files with macros have been stored in a compressed mode on the diskette and must be "exploded" to create the "working" files listed in Section 2. Files may be "exploded" as follows:

- Start from the drive prompt of the desired directory (e.g., C:\123\PA_data\).
- Copy the appropriate "compressed" file for your spreadsheet software application as specified in Section 2 from the Spreadsheet Master Diskette to a directory resident on your hard drive.

Table A-1. File Designations for Various Software Spreadsheets - Single Sample Per Day Format

Single Component Spreadsheets	for DOS	for WINDOWS		
	LOTUS 123 2.4	LOTUS 123 5.0	EXCEL 4.0 or 5.0	QUATTRO PRO 5.0
Compressed Files	D_L24.EXE	D_L5W.EXE	D_XCL.EXE	D_QP.EXE
Working Files	D_123R24.WK1	D_123R5W.WK4	D_EXCEL4.XLS	D_QUTPRO.WB1
External Format Files	D_123R24.FMT	None	None	None
External Macros	None	None	MACRO1.XLM	None

Table A-2. File Designations for Various Software Spreadsheets - Multiple Sample Per Day Format

Multiple Component Spreadsheets	for DOS	for WINDOWS		
	LOTUS 123 2.4	LOTUS 123 5.0	EXCEL 4.0 or 5.0	QUATTRO PRO 5.0
Compressed Files	4_L24.EXE	4_L5W.EXE	4_XCL.EXE	4_QP.EXE
Working Files	4_123R24.WK1	4_123R5W.WK4	4_EXCEL4.XLS	4_QUTPRO.WB1
External Format Files	4_123R24.FMT	None	None	None
External Macros	None	None	MACRO4.XLM	None

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For non-WINDOWS applications, simply type the compressed filename with the .EXE extension and press return (e.g., type D_L5W.EXE at the C:\123\PA_data> prompt and press return).

- For WINDOWS applications, select Run from the File submenu and type the compressed filename with the .EXE extension and click on OKAY.

When control of the keyboard is returned to the user:

- Copy the required "External" format and macro files and "DATA1.WK1" from the Master Diskette to the directory containing the newly created "working" file.
- Return to the menu or WINDOWS screen.
- Select the icon or menu option to enter the spreadsheet package (e.g., click on the LOTUS 123 Release 5.0 icon). (NOTE: WYSIWYG needs to be invoked for the LOTUS 123 Release 2.4 spreadsheets.)
- Open the newly created "working" file as specified in Section 2 and save the file under a new file name. Please note: The EXCEL spreadsheets require that the macro files "MACRO1.XLM" or "MACRO4.XLM" are opened in addition to the spreadsheet file. Once the macro file has been opened, utilize the HIDE feature under the WINDOW command to redisplay the data entry worksheet.
- Proceed to Section 4 to run the macro self-test or Section 5 to begin entering performance data.

Section 4 - Running the Macro Self-Test

Should users have concerns about the compatibility of the spreadsheets and macros and their spreadsheet software package, they should conduct a self-test of the macro. The self-test output will resemble the attached Example Performance Assessment Data Collection Spreadsheet Output. Run the self-test as follows:

- Open the "working" file created in Section 3 (refer to Section 2 table file name) and save/rename the file.
- For a single component (one sample per day) self-test: Copy range B1..B365 from the file "DATA1.WK1" to cell B49..B413. Go to the Single Component portion of Section 5 and proceed.

- For a multiple component (up to six samples per day) self-test: Copy range D1..I365 from the file "DATA1.WK1" to Cell D49..I413. Go to the Multiple Component portion of Section 5 and proceed.
- Activate the macro using steps specified in Section 6.
- Print output using steps specified in Section 7.

The printed output should resemble the attached Example Performance Assessment Data Collection Spreadsheet Output. Please note: Outputs generated will vary slightly due to differences in the spreadsheet software package being used. Should the macro prove inoperable, reinstall the files from the Master Diskette and repeat the process and/or refer to Section 8 prior to requesting assistance.

Section 5 - Entering Performance Data

Prior to entering data, users should set the worksheet recalculation mode to manual to decrease data entry and macro execution time. To begin the data entry process:

- Open or Retrieve the working and external files specified in Section 3.
- Enter the appropriate Utility/Plant specific information in cells F39..F44.
- Enter the last two digits of the start year in cell B40 (e.g., 94 for 1994).
- Enter the start month in cell B41 (e.g., 7 for July).
- Data entry should always begin on the first of each month and include the entire month.
- All graphical and percentile table computations key on the entered dates. Therefore, no dates should be left blank.

For Single Component Spreadsheets (for use when entering one value per day):

- The formula residing in cell A50 will automatically increase the date entered in A49 by one day. Copy cell A50 to A51, A52, A53 and so on to the end of the year or the data entry period.
- After the column of dates has been generated in Column A, begin entering data (turbidity or particle counts, etc.) one value at a time in cell B49, B50, B51, etc. until all data has been entered. Note: The data entry section of the spreadsheet is highlighted in yellow. Skip cells when no data exists for those days.
- Do NOT enter data in Column A.

For Multiple Component Spreadsheets (for use when entering six values per day - e.g., 4-hour data):

- The formula residing in cell A50 will automatically increase the date entered into A49 by one day. Copy cell A50 to A51, A52, A53 and so on to the end of the year or the data entry period.
- The formula residing in cell B49 calculates the maximum value of the six daily entries. Copy cell B49 to B50, B51, B52 and so on to the end of the year or until the end of the data entry period. Note: Until data is entered in Columns D through I, the value in Column B will show an "ERR" message. Ignore this message.
- After the column of dates and formulas for daily maximums has been generated in Columns A and B, begin entering the 40 hour data (turbidity or particle counts, etc.) one value at a time in cells D49 and E49 and F49 and G498 and H49 and I49, etc. until all data has been entered. Note: The data entry section is highlighted in yellow. Skip cells when no data exists for those days.
- Do NOT enter data in Column A or B.
- After all data has been entered the worksheet should be saved with a new file name. This will protect the data in the unlikely event of error during execution of the macro.

Section 6 - Activating the Macros

To activate the macros when using:

- LOTUS 123 Release 2.4 for DOS, press the ALT and F3 keys simultaneously. Highlight A and press <Enter> or <Return>. Note: the LOTUS

123 Release 2.4 spreadsheets generate graphs during execution, and users must press <Return> or <Enter> when graphics appear on the screen to proceed through execution. These graphs summarize previous entries and may be confusing during the first entry process.

- LOTUS 123 Release 5.0 for WINDOWS or QUATTRO PRO Release 5.0 for WINDOWS, position and click the mouse button on any button contained within the spreadsheet labeled "Run Macro."
- EXCEL Release 4.0 or 5.0 for WINDOWS, press the CTRL and A keys simultaneously.

Section 7 - Printing Spreadsheet Output

To print the percentile tables and graphs generated during macro execution using:

- LOTUS 123 Release 2.4, invoke the WYSIWYG add-in and print the previously defined range by pressing <Shift:> then selecting <Print> and <Go> after the system has been configured to the user's printer. If the WYSIWYG add-in is unavailable, users should generate and print the graph PIC files Filtyear.PIC and Filtprob.PIC using the LOTUS Printgraph procedures.
- LOTUS 123 Release 5.0 or QUATTRO PRO Release 5.0 or EXCEL Release 4.0 or 5.0, follow printing techniques specified for WINDOWS applications by clicking on a printer icon (which will print the previously defined range) or select PRINT from the File submenu (and select "previously defined range") when the system requests a printing option. Users may have to adjust margins to accommodate individual applications in order to print output to a single sheet of paper.

Section 8 - Important Rules to Remember When Using the Spreadsheets and Macros

- Please remember that the spreadsheets and macros were developed and tested to operate under the software systems and release versions specified in Section 2. The spreadsheets and macros may, however, execute under other release versions. Users have had success using the LOTUS 123 Release 2.4 version for DOS spreadsheet in a Release 2.3 operating system. Also, some users have been able to execute the WINDOWS QUATTRO PRO 5.0 spreadsheet in a DOS environment by typing ALT and F2 in lieu of depressing the RUN MACRO button which is only visible in WINDOWS applications. Please remember that these exceptions have not been thoroughly tested by the Partnership for Safe Water software development group.
- The only DOS version of the spreadsheets is LOTUS 123 Release 2.4. All other spreadsheets are WINDOWS applications.
- Make certain that the correct spreadsheet and macros are used for analyzing the appropriate data based on the number of daily samples (e.g., 1 sample per day versus 6 samples per day).
- Do NOT enter more than 12 months of data on any spreadsheet. Users should create a separate spreadsheet for each 12 months worth of data. The spreadsheet will inaccurately depict

percentiles in the table and on the probability graph when data entry exceeds one year.

- Do NOT expect the percentile tables and trend and percentile graphs to update with correct values until the macros for the spreadsheets have been executed. Prior to macro execution, the spreadsheet percentile tables and graphs contain data generated from the test data.
- When using the EXCEL spreadsheets do NOT open both external macro files simultaneously. Use only the designated macro for the appropriate spreadsheet.
- Individual spreadsheets need to be created for handling raw, settled, and filtered/finished data. Memory constraints preclude accommodating all sampling points within a single spreadsheet.
- Table and graph titles, when working in WINDOWS applications, may be edited by simply positioning the mouse pointer on the appropriate cells and double clicking the cell. This enters the edit mode.
- When using the DOS spreadsheet, the titles may be edited by depressing the F2 key in the appropriate cell and typing in the changes. Users must enter the graph mode to modify the chart/graph titles.

Appendix B

Drinking Water Treatment Plant (DWTP) Advisor Software

Development of the DWTP Advisor

The DWTP Advisor is a computer software application designed as an “expert system” to provide assistance in the evaluation of drinking water treatment plants. The program was based on the source document Interim Handbook: Optimizing Water Treatment Plant Performance Using the Composite Correction Program Approach (1). The Interim Handbook is the predecessor document to this handbook, of which this appendix is a part. The software was developed to assist personnel responsible for improving the performance of existing water treatment plants in order to achieve compliance with the 1989 SWTR.

The system consists of two major components: Major Unit Process Evaluation and Performance Limiting Factors. These two component parts were designed to work together. The evaluator, therefore, cannot choose to use only one of the program's components. In addition, the evaluator cannot modify the loading values, some of which are currently outdated. The software leads the evaluator through a series of questions and provides responses based on the experience and judgment of a group of experts that were used to delineate the logic for the program. The complexity of the multiple interrelated factors limiting performance and the uniqueness of individual plants makes production of an expert system with broad scale application difficult. This coupled with the fact that the program has not been updated for several years, should make persons considering use of the software aware of these inherent limitations.

Even though an expert system like the DWTP Advisor would theoretically have many uses, its current level of development limits its usefulness in conducting CPEs. Persons familiar with the fundamental CCP concepts and who understand the limitations of the software, however, may find it a useful tool.

Technical Information

Hardware Requirements

The DWTP Advisor requires an IBM AT or compatible computer with the following components:

- A hard disk with at least 5.0 megabytes of free space
- At least 640 Kbytes of RAM (560,000 bytes user-available)
- A high density floppy disk drive (5.25” 1.2 MB or 3.5” 1.4 MB)
- DOS version 3.0 or higher
- A printer (EPSON compatible) configured as system device PRN (optional)

If you installed the DWTP Advisor, but are unable to run the program, you may need to check your computer's memory configuration. Although your computer may have the minimum memory required, memory resident programs may use some of this memory. “User-available” memory is the amount of memory remaining after the operating system and memory resident programs are loaded. If memory resident programs are installed and adequate memory is not available for the DWTP Advisor, an error message will appear on the screen when you attempt to run the program. If this occurs, memory resident programs should be disabled (e.g., by editing your computer's configuration files, config.sys and autoexec.bat) and your computer rebooted before running the system. To check the status of your computer's disk and available memory, run the MS-DOS CHKDSK program by typing CHKDSK and pressing <Enter>. For more information, see the MS-DOS manual that came with your computer or consult your PC support staff.

Software Specifications

The DWTP Advisor has been developed using several commercially available software tools. The system interface was developed using Turbo Pascal 6. The “reasoning” or evaluating portion of the system uses the expert system shell 1ST Class. The system also consists of data files in dBase.dbf format.

Contents of the System

The DWTP Advisor package includes one double-sided, high density disk and complete User Documentation.

A copy of the Water Advisor Software may be obtained by contacting:

ORD Publications (G-72)
26 West Martin Luther King Drive
U. S. Environmental Protection Agency
Cincinnati, Ohio 45268-1072
Telephone: 513-569-7562
Fax: 513-569-7566

Ask for: Drinking Water Treatment Plant
Advisor Software: 625/R-96/02

Appendix C
Major Unit Process Capability Evaluation
Performance Potential Graph Spreadsheet Tool
for the Partnership for Safe Water

Section 1	Background on the Major Unit Process Capability Evaluation
Section 2	The Performance Potential Graph Spreadsheet Tool
Section 3	Selecting the Appropriate Spreadsheet for Your Application
Section 4	Loading the Spreadsheet
Section 5	Entering Plant Information/Data
Section 6	Printing Spreadsheet Output
Section 7	Important Rules to Remember When Using the Performance Potential Graph Spreadsheet Tool
Figure C-1	Example performance potential graph output for LOTUS 123 files.
Figure C-2	Example performance potential graph output for EXCEL and QUATTRO PRO files.
Figure C-3	Example performance potential graph data entry section for all files.
Figure C-4	Performance potential graph data entry guide.
Table C-1	Various Software Spreadsheets - The Designations for Performance Potential Graph
Table C-2	Major Unit Process Evaluation Criteria

Section 1 - Background on the Major Unit Process Capability Evaluation

Water treatment plants are designed to take a raw water source of variable quality and produce a consistent, high quality finished water using multiple treatment processes in series to remove turbidity and prevent microbial contaminants from entering the finished water. Each treatment process represents a barrier to prevent the passage of microbial contaminants and particulates in the plant. By providing multiple barriers, any microorganisms passing one unit process can possibly be removed in the next, minimizing the likelihood of microorganisms passing through the entire treatment system and surviving in water supplied to the public.

The performance potential graph (see Figures C-1 and C-2) is used to characterize capabilities of individual treatment processes to continuously function as a barrier for removing particulates and harmful pathogens. Each of the major unit processes is assessed with respect to its capability to consistently contribute to an overall plant treated water quality of less than 0.1 NTU turbidity during peak flows. Specific considerations are given only to process basin size and capability under optimum conditions. Limitations in process capability due to minor deficiencies or incorrect operation (e.g., degraded baffles which allow short-circuiting or improper process control) do not contribute to development of the performance potential graph. These operational or minor modification limitations are addressed during the evaluation of the other aspects of the treatment plant conducted as part of the *Partnership for Safe Water* self-assessment procedures.

Specific performance goals for the flocculation, sedimentation, filtration, and disinfection unit processes are used when developing the performance potential graph. These include settled water turbidities of less than 2 NTU and filtered effluent turbidities of less than 0.1 NTU. Capabilities of the disinfection process are assessed based on the CT values outlined in a USEPA guidance manual for meeting filtration and disinfection requirements. Rated capacities are determined for each of the unit processes based on industry standard loading rates and detention times with demonstrated capability to achieve specific unit process performance goals. These evaluation criteria are defined in Table C-2 of this appendix. The resulting unit process rated capacities are compared to the peak instantaneous operating flow for the treatment plant. Any unit process rated capacities which do not exceed the plant's peak instantaneous operating flow are suspect in their ability to consistently meet desired

performance goals that will maximize protection against the passage of microbial contaminants through the treatment plant. Specific interpretation of the results of the performance potential graph are discussed in Section 3 of the *Partnership for Safe Water* self-assessment procedures. It is important that the

Figure C-1. Example performance potential graph spreadsheet output for LOTUS 123 releases.

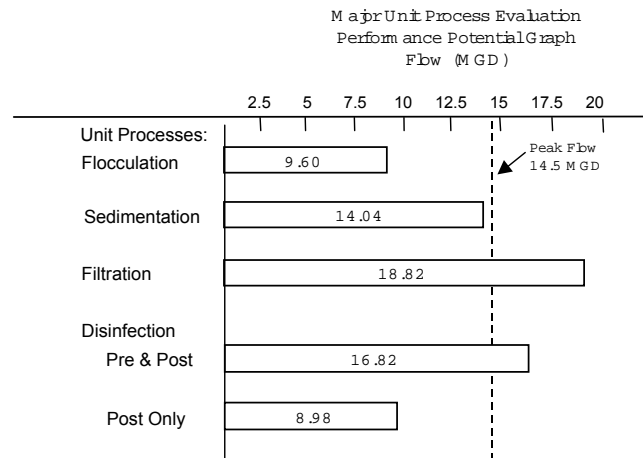
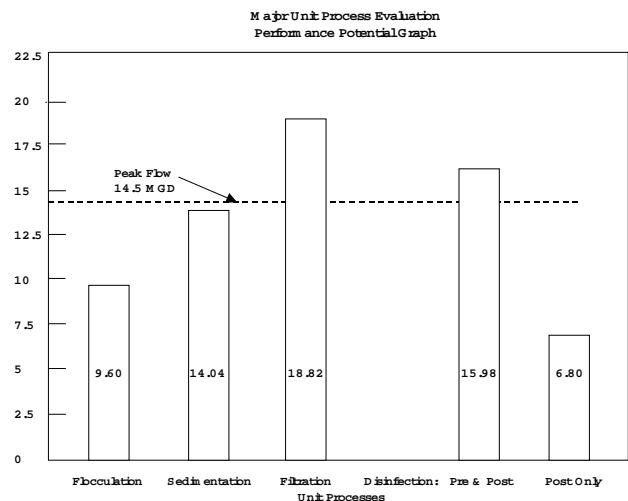


Figure C-2. Example performance potential graph spreadsheet output for EXCEL and QUATTRO PRO releases.



evaluator recognize that the guidance provided by this computer software should not exceed the evaluators' judgement in projecting unit process capability. Options to change loading rate projections to values different from those provided are

available and should be considered if data or the evaluators' experience justifies the modification.

Section 2 - The Performance Potential Graph Spreadsheet Tool

Spreadsheets have been generated to assist Utility Partners in creating the performance potential graph required for Section 3 for use in the *Partnership for Safe Water* self-assessment procedures. Generating the performance potential graph requires opening the appropriate spreadsheet file and entering specific physical plant information in the defined cells (see Figure C-4). A performance potential graph will be generated automatically. Rated capacities for each unit process are generated from user-defined criteria as well as from criteria defined in Table C-2 and discussed in Section 3 of the *Partnership for Safe Water* self-assessment procedures. The user may print a hard copy of the performance potential graph by following steps defined in Section 6 of this appendix.

Users requiring expanded instructions for entering appropriate information in the spreadsheet cells should refer to Figure C-3. Should users require additional assistance in preparing a performance potential graph using the spreadsheet, please contact Eric Bissonette of USEPA/OGWDW Technical Support Division at (513) 569-7933.

Section 3 - Selecting the Appropriate Spreadsheet for Your Application

Performance Potential Graph Spreadsheets have been developed in LOTUS 123 Release 2.4 for DOS and 5.0 for WINDOWS, EXCEL Release 4.0 and 5.0 for WINDOWS, and QUATTRO PRO Release 5.0 for WINDOWS software systems. Select the files corresponding to your application and data entry needs from Table C-1 and proceed to Section 4.

Table C-1. File Designations for Various Software Spreadsheets - Performance Potential Graph

	for DOS	for WINDOWS
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Performance Potential Graphs	LOTUS 123 2.4	LOTUS 123 5.0	EXCEL 4.0 or 5.0	QUATTRO PRO 5.0
Working Files	PPG.WK1	PPG.WK4	PPGXLC-XLS	PPGQP.WB1
External Format Files	PPG.FMT	None	None	None

Section 4 - Loading the Spreadsheet

- Copy the required working file and external format file from the Master Diskette to a directory resident on the hard drive of your computer. Do NOT work from the files contained on the Master Diskette.
- Enter your spreadsheet software by selecting the appropriate icon or menu option (e.g., click on the LOTUS 123 Release 5.0 icon). (Note: WYSIWYG needs to be invoked for the LOTUS 123 Release 2.4 spreadsheets.)
- Open the working file as specified in Section 3 and save the file under a new file name.

Section 5 - Entering Plant Information

Each spreadsheet contains a data entry section and a chart which depicts the resulting individual unit process rated capacities. The LOTUS 123 spreadsheets generate a performance potential graph with the unit process rated capacities characterized by horizontal bars (see Figure C-1). Contrarily, the EXCEL and QUATTRO PRO performance potential graphs characterize the unit process capacities by vertical bars (see Figure C-2). The data entry sections are identical for the LOTUS 123, EXCEL, and QUATTRO PRO performance potential graph files (see Figure C-3).

- Begin entering appropriate physical plant data in cells B31..B71 and E32..E69. Figure C-4 contains in-depth description of the acceptable entries for each of the cells in the spreadsheet.
- The entered physical plant data will appear in blue. Cells containing black values are calculated from data entered in other cells and cannot be modified.

Table C-2. Major Unit Process Evaluation Criteria*

Flocculation		Hydraulic Detention Time
Base		20 minutes
Single Stage	Temp ≤ 0.5°C	+10 minutes
	Temp > 0.5°C	+5 minutes
Multiple Stages	Temp ≤ 0.5°C	+0 minutes
	Temp > 0.5°C	-5 minutes

Filtration		
	Air Binding	Loading Rate
Sand Media	None	2.0 gpm/ft²
	Moderate	1.5 gpm/ft²
	High	1.0 gpm/ft²
Dual/Mixed Media	None	4.0 gpm/ft²
	Moderate	3.0 gpm/ft²
	High	2.0 gpm/ft²
Deep Bed	None	6.0 gpm/ft²
	Moderate	4.5 gpm/ft²
	High	3.0 gpm/ft²

Sedimentation		Surface Overflow Rate
Rectangular/Circular/Contact	Basin Depth	
Turbidity Mode	> 14 ft	0.7 gpm/ft²
	12 - 14 ft	0.6 gpm/ft²
	10 - 12 ft	0.5 - 0.6 gpm/ft²
	<10 ft	0.1 - 0.5 gpm/ft²
Softening Mode	> 14 ft	1.0 gpm/ft²
	12 - 14 ft	0.75 gpm/ft²
	10 - 12 ft	0.5 - 0.75 gpm/ft²
	<10 ft	0.1 - 0.5 gpm/ft²
Vertical (>45°) Tube Settlers		
Turbidity Mode	> 14 ft	2.0 gpm/ft²
	12 - 14 ft	1.5 gpm/ft²
	10 - 12 ft	1.0 - 1.5 gpm/ft²
	<10 ft	0.2 - 1.0 gpm/ft²
Softening Mode	> 14 ft	2.5 gpm/ft²
	12 - 14 ft	2.0 gpm/ft²
	10 - 12 ft	1.5 - 2.0 gpm/ft²
	<10 ft	0.7 - 1.5 gpm/ft²
Horizontal (<45°) Tube Settlers		2.0 gpm/ft²
Adsorption Clarifier		9.0 gpm/ft²
Lamella Plates		4.0 gpm/ft²
SuperPulsator		1.5 gpm/ft²
with tubes		1.7 gpm/ft²
Claricone Turbidity Mode		1.0 gpm/ft²
Claricone Softening Mode		1.5 gpm/ft²

*If long term (12-month) data monitoring indicates capability to meet performance goals at higher loading rates, then these rates can be used.

Renner, R.C., B.A. Hegg, J.H. Bender, and E.M. Bissonette. 1991. *Handbook - Optimizing Water Treatment Plant Performance Using the Composite Correction Program*. EPA 625/9-91/027. Cincinnati, OH: USEPA.

AWWARF Workshop. 1995. *Plant Optimization Workshop*. Colorado Springs, CO: AWWARF.

Eastern Research Group, Inc. 1992. *Water Advisor Utilizing the CCP Approach (Expert System)*. USEPA Work Assignment No. 7391-55. Eastern Research Group, Inc., Arlington, MA.

USEPA, AWWA, AWWARF, Association of Metropolitan Water Agencies, Association of State Drinking Water Administrators, and National Association of Water Companies. 1995. *Partnership for Safe Water Voluntary Water Treatment Plant Performance Improvement Program*.

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Each major unit process section contains a suggested and assigned evaluation criteria cell (e.g., the flocculation section contains a suggested and an assigned hydraulic detention time cell). The suggested loading rates, summarized in Table C-2 of this appendix, for specified situations are representative of conditions in which identified unit processes have demonstrated effectiveness in serving as a multiple barrier in the prevention of cyst and microorganism passage through the treatment plant.

- The actual rated capacities for each of the unit processes are calculated from the loading rates entered into the cells labeled “assigned loading rates.” Users must enter a value into the assigned cell, either selecting the “suggested” value or entering their own loading rate.
- The performance potential graph contained at the top of each spreadsheet will instantaneously update after each data entry. Complete the entire data entry process prior to proceeding to printing the spreadsheet output described in Section 6.

Section 6 - Printing Spreadsheet Output

To print the performance potential graph using:

- LOTUS 123 Release 2.4 for DOS, invoke the WYSIWYG add-in and print the previously defined range by pressing <Shift :> then selecting <Print> and <Go> after the system has been configured to the user’s printer. If the WYSIWYG add-in is unavailable, users should generate and print the graph PIC file

- LOTUS 123 Release 5.0 for WINDOWS, or QUATTRO PRO Release 5.0 for WINDOWS, or EXCEL Release 4.0 or 5.0 for WINDOWS, follow printing techniques specified for WINDOWS applications by clicking on a printer icon (which will print the previously defined range) or select PRINT from the File submenu (and select “previously defined range” when the system requests a printing option). Users may have to adjust margins to accommodate individual applications in order to print output to a single sheet of paper.

Section 7 - Important Rules to Remember When Using the Performance Potential Graph Spreadsheet Tool

- Cells containing “Black” values are calculated from other pertinent data entries and cannot be modified because the cells have been protected.
- The actual rated capacities for each of the unit processes are calculated from the loading rate entered into the cells labeled “assigned loading rates.” Users must enter a value into the assigned cell, either selecting the “suggested” value or entering their own loading rate.
- The external format file must be copied from the Master Diskette to the same directory as the working file or the Performance Potential Graph will not be visible when using LOTUS 123 Release 2.4 for DOS.

PPG.PIC, using the LOTUS Printgraph procedures.

Appendix D
CT Values for Inactivation of Giardia and Viruses
by Free Cl₂ and Other Disinfectants

All tables in this appendix are taken from *Guidance Manual for Compliance With the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources*, Appendix E, Science and Technology Branch, Criteria and Standards Division, Office of Drinking Water, USEPA, Washington, D.C., October 1989.

Table D-7. CT Values for Inactivation of Viruses by Free Chlorine

pH	Log Inactivation					
	2.0		3.0		4.0	
Temperature (C)	6-9	10	6-9	10	6-9	10
0.5	6	45	9	66	12	90
5	4	30	6	44	8	60
10	3	22	4	33	6	45
15	2	15	3	22	4	30
20	1	11	2	16	3	22
25	1	7	1	11	2	15

Table D-8. CT Values for Inactivation of *Giardia* Cysts by Chlorine Dioxide

Temperature (C)						
	<=1	5	10	15	20	25
0.5-log	10	4.3	4	3.2	2.5	2
1-log	21	8.7	7.7	6.3	5	3.7
1.5-log	32	13	12	10	7.5	5.5
2-log	42	17	15	13	10	7.3
2.5-log	52	22	19	16	13	9
3-log	63	26	23	19	15	11

Table D-9. CT Values for Inactivation of Viruses by Chlorine Dioxide pH 6-9

Temperature (C)						
	<=1	5	10	15	20	25
2-log	8.4	5.6	4.2	2.8	2.1	1.4
3-log	25.6	17.1	12.8	8.6	6.4	4.3
4-log	50.1	33.4	25.1	16.7	12.5	8.4

Table D-10. CT Values for Inactivation of *Giardia* Cysts by Ozone

Temperature (C)						
	<=1	5	10	15	20	25
0.5-log	0.48	0.32	0.23	0.16	0.1	0.08
1-log	0.97	0.63	0.48	0.32	0.2	0.16
1.5-log	1.5	0.95	0.72	0.48	0.36	0.24
2-log	1.9	1.3	0.95	0.63	0.48	0.32
2.5-log	2.4	1.6	1.2	0.79	0.6	0.4
3-log	2.9	1.9	1.43	0.95	0.72	0.48

Table D-11. CT Values for Inactivation of Viruses by Ozone

Temperature (C)						
	<=1	5	10	15	20	25
2-log	0.9	0.6	0.5	0.3	0.25	0.15
3-log	1.4	0.9	0.8	0.5	0.4	0.25
4-log	1.8	1.2	1	0.6	0.5	0.3

Table D-12. CT Values for Inactivation of *Giardia* Cysts by Chloramine pH 6-9

Temperature (C)						
	<=1	5	10	15	20	25
0.5-log	635	365	310	250	185	125
1-log	1270	735	615	500	370	250
1.5-log	1900	1100	930	750	550	375
2-log	2535	1470	1230	1000	735	500
2.5-log	3170	1830	1540	1250	915	625
3-log	3800	2200	1850	1500	1100	750

Table D-13. CT Values for Inactivation of Viruses by Chloramine

Temperature (C)						
	<=1	5	10	15	20	25
2-log	1243	857	643	428	321	214
3-log	2063	1423	1067	712	534	356
4-log	2883	1988	1491	994	746	497

Table D-14. CT Values for Inactivation of Viruses by UV

Log Inactivation	
2	3
21	36

Appendix E
Performance Limiting Factors Summary Materials
and Definitions

CPE Factor Summary Sheet Terms

Plant Type	Brief but specific description of plant type (e.g., conventional with flash mix, flocculation, sedimentation, filtration and chlorine disinfection; or direct filtration with flash mix, flocculation and chlorine disinfection).
Source Water	Brief description of source water (e.g., surface water including name of water body).
Performance Summary	Brief description of plant performance based on performance assessment component of the CPE (i.e., ability of plant to meet optimized performance goals).
Ranking Table	A listing of identified performance limiting factors that directly impact plant performance and reliability.
Rank	Relative ranking of factor based on prioritization of all "A" and "B" rated factors identified during the CPE.
Rating	<p>Rating of factor based on impact on plant performance and reliability:</p> <p>A — Major effect on a long-term repetitive basis</p> <p>B — Moderate effect on a routine basis or major effect on a periodic basis</p> <p>C — Minor effect</p>
Performance Limiting Factor (Category)	Factor identified from Checklist of Performance Limiting Factors, including factor category (e.g., administration, design, operation, and maintenance).
Notes	Brief listing of reasons each factor was identified (e.g., lack of process control testing, no defined performance goals).

[illegible]

Rating Description

- A — Major effect on long-term repetitive basis.
B — Moderate effect on a routine basis or major effect on a periodic basis.
C — Minor effect.

Performance Limiting Factors Notes	
Factor	Notes
	•
	•
	•
	•
	•
	•
	•
	•

Checklist of Performance Limiting Factors

A. ADMINISTRATION

1. Plant Administrators
 - a. ☐ Policies _____
 - b. ☐ Familiarity With Plant Needs _____
 - c. ☐ Supervision _____
 - d. ☐ Planning _____
 - e. ☐ Complacency _____
 - f. ☐ Reliability _____
 - g. ☐ Source Water Protection _____
2. Plant Staff
 - a. ☐ Number _____
 - b. ☐ Plant Coverage _____
 - c. ☐ Personnel Turnover _____
 - d. ☐ Compensation _____
 - e. ☐ Work Environment _____
 - f. ☐ Certification _____
3. Financial
 - a. ☐ Operating Ratio _____
 - b. ☐ Coverage Ratio _____
 - c. ☐ Reserves _____

B. DESIGN

1. Source Water Quality
 - a. ☐ Microbial Contamination _____
2. Unit Process Adequacy
 - a. ☐ Intake Structure _____
 - b. ☐ Presedimentation Basin _____
 - c. ☐ Raw Water Pumping _____
 - d. ☐ Flow Measurement _____
 - e. ☐ Chemical Storage and Feed _____
 - Facilities _____
 - f. ☐ Flash Mix _____
 - g. ☐ Flocculation _____
 - h. ☐ Sedimentation _____
 - i. ☐ Filtration _____
 - j. ☐ Disinfection _____
 - k. ☐ Sludge/Backwash Water _____
 - Treatment and Disposal _____

-
- 3. Plant Operability
 - a. ☐ Process Flexibility _____
 - b. ☐ Process Controllability _____
 - c. ☐ Process Instrumentation/
Automation _____
 - d. ☐ Standby Units for Key
Equipment _____
 - e. ☐ Flow Proportioning _____
 - f. ☐ Alarm Systems _____
 - g. ☐ Alternate Power Source _____
 - h. ☐ Laboratory Space and Equipment _____
 - i. ☐ Sample Taps _____

C. OPERATION

- 1. Testing
 - a. ☐ Process Control Testing _____
 - b. ☐ Representative Sampling _____
- 2. Process Control
 - a. ☐ Time on the Job _____
 - b. ☐ Water Treatment Understanding _____
 - c. ☐ Application of Concepts and
Testing to Process Control _____
- 3. Operational Resources
 - a. ☐ Training Program _____
 - b. ☐ Technical Guidance _____
 - c. ☐ Operational Guidelines/Procedures _____

D. MAINTENANCE

- 1. Maintenance Program
 - a. ☐ Preventive _____
 - b. ☐ Corrective _____
 - c. ☐ Housekeeping _____
- 2. Maintenance Resources
 - a. ☐ Materials and Equipment _____
 - b. ☐ Skills or Contract Services _____

Definitions for Assessing Performance Limiting Factors

NOTE: The following list of defined factors is provided to assist the evaluator with identifying performance limitations associated with protection against microbial contaminants in water treatment systems. Performance limiting factors are described below using the following format.

A. CATEGORY

1. Subcategory

a. Factor Name

- ◆ Factor description

➤ *Example of factor applied to specific plant or utility*

A. Administration

1. Plant Administrators

a. Policies

- ◆ Do existing policies or the lack of policies discourage staff members from making required operation, maintenance, and management decisions to support plant performance and reliability?
 - *Utility administration has not communicated a clear policy to optimize plant performance for public health protection.*
 - *Multiple management levels within a utility contribute to unclear communication and lack of responsibility for plant operation and performance.*
 - *Cost savings is emphasized by management at the expense of plant performance.*
 - *Utility managers do not support reasonable training and certification requests by plant staff.*
 - *Administration continues to allow connections to the distribution system without consideration for the capacity of the plant.*

b. Familiarity With Plant Needs

- ◆ Do administrators lack first-hand knowledge of plant needs?
 - *The utility administrators do not make plant visits or otherwise communicate with plant staff.*
 - *Utility administrators do not request input from plant staff during budget development.*

c. Supervision

- ◆ Do management styles, organizational capabilities, budgeting skills, or communication practices at any management level adversely impact the plant to the extent that performance is affected?
 - *A controlling supervision style does not allow the plant staff to contribute to operational decisions.*
 - *A plant supervisor's inability to set priorities for staff results in insufficient time allocated for process control.*

d. Planning

- ◆ Does the lack of long range planning for facility replacement or alternative source water quantity or quality adversely impact performance?
 - *A utility has approved the connection of new customers to the water system without considering the water demand impacts on plant capacity.*
 - *An inadequate capital replacement program results in utilization of outdated equipment that cannot support optimization goals.*

-
- e. Complacency
 - ◆ Does the presence of consistent, high quality source water result in complacency within the water utility?
 - *Due to the existence of consistent, high quality source water, plant staff are not prepared to address unusual water quality conditions.*
 - *A utility does not have an emergency response plan in place to respond to unusual water quality conditions or events.*
 - f. Reliability
 - ◆ Do inadequate facilities or equipment, or the depth of staff capability, present a potential weak link within the water utility to achieve and sustain optimized performance?
 - *Outdated filter control valves result in turbidity spikes in the filtered water entering the plant clearwell.*
 - *Plant staff capability to respond to unusual water quality conditions exists with only the laboratory supervisor.*
 - g. Source Water Protection
 - ◆ Does the water utility lack an active source water protection program?
 - *The absence of a source water protection program has resulted in the failure to identify and eliminate the discharge of failed septic tanks into the utility's source water lake.*
 - *Utility management has not evaluated the impact of potential contamination sources on water quality within their existing watershed.*
2. Plant Staff
- a. Number
 - ◆ Does a limited number of people employed have a detrimental effect on plant operations or maintenance?
 - *Plant staff are responsible for operation and maintenance of the plant as well as distribution system and meter reading, limiting the time available for process control testing and process adjustments.*
 - b. Plant Coverage
 - ◆ Does the lack of plant coverage result in inadequate time to complete necessary operational activities? (Note: This factor could have significant impact if no alarm/shutdown capability exists - see design factors).
 - *Staff are not present at the plant during evenings, weekends, or holidays to make appropriate plant and process control adjustments.*
 - *Staff are not available to respond to changing source water quality characteristics.*
 - c. Personnel Turnover
 - ◆ Does high personnel turnover cause operation and maintenance problems that affect process performance or reliability?
 - *The lack of support for plant needs results in high operator turnover and, subsequently, inconsistent operating procedures and low staff morale.*
 - d. Compensation
 - ◆ Does a low pay scale or benefit package discourage more highly qualified persons from applying for operator positions or cause operators to leave after they are trained?
 - *The current pay scale does not attract personnel with sufficient qualifications to support plant process control and testing needs.*
 - e. Work Environment
 - ◆ Does a poor work environment create a condition for "sloppy work habits" and lower operator morale?
 - *A small, noisy work space is not conducive for the recording and development of plant data.*
 - f. Certification
 - ◆ Does the lack of certified personnel result in poor O & M decisions?

-
- *The lack of certification hinders the staff's ability to make proper process control adjustments.*
 - 3. Financial
 - a. Operating Ratio
 - ◆ Does the utility have inadequate revenues to cover operation, maintenance, and replacement of necessary equipment (i.e., operating ratio less than 1.0)?
 - *The current utility rate structure does not provide adequate funding and limits expenditures necessary to pursue optimized performance (e.g., equipment replacement, chemical purchases, spare parts).*
 - b. Coverage Ratio
 - ◆ Does the utility have inadequate net operating profit to cover debt service requirements (i.e., coverage ratio less than 1.25)?
 - *The magnitude of a utility's debt service has severely impacted expenditures on necessary plant equipment and supplies.*
 - c. Reserves
 - ◆ Does the utility have inadequate reserves to cover unexpected expenses or future facility replacement?
 - *A utility has a 40-year-old water treatment plant requiring significant modifications; however, no reserve account has been established to fund these needed capital expenditures.*

B. Design

- 1. Source Water Quality
 - a. Microbial Contamination
 - ◆ Does the presence of microbial contamination sources in close proximity to the water treatment plant intake impact the plant's ability to provide an adequate treatment barrier?
 - *A water treatment plant intake is located downstream of a major wastewater treatment plant discharge and is subject to a high percentage of this flow during drought periods.*
- 2. Unit Process Adequacy
 - a. Intake Structure
 - ◆ Does the design of the intake structure result in excessive clogging of screens, build-up of silt, or passage of material that affects plant equipment?
 - *The location of an intake structure on the outside bank of the river causes excessive collection of debris, resulting in plugging of the plant flow meter and static mixer.*
 - *The design of a reservoir intake structure does not include flexibility to draw water at varying levels to minimize algae concentration.*
 - b. Presedimentation Basin
 - ◆ Does the design of an existing presedimentation basin or the lack of a presedimentation basin contribute to degraded plant performance?
 - *The lack of flexibility with a presedimentation basin (i.e., number of basins, size, bypass) causes excessive algae growth, impacting plant performance.*
 - *A conventional plant treating water directly from a "flashy" stream experiences performance problems during high turbidity events.*

-
- c. Raw Water Pumping
- ◆ Does the use of constant speed pumps cause undesirable hydraulic loading on downstream unit processes?
 - *The on-off cycle associated with raw water pump operation at a plant results in turbidity spikes in the sedimentation basin and filters.*
- d. Flow Measurement
- ◆ Does the lack of flow measurement devices or their accuracy limit plant control or impact process control adjustments?
 - *The flow measurement device in a plant is not accurate, resulting in inconsistent flow measurement records and the inability to pace chemical feed rates according to flow.*
- e. Chemical Storage and Feed Facilities
- ◆ Do inadequate chemical storage and feed facilities limit process needs in a plant?
 - *Inadequate chemical storage facilities exist at a plant, resulting in excessive chemical handling and deliveries.*
 - *Capability does not exist to measure and adjust the coagulant and flocculant feed rates.*
- f. Flash Mix
- ◆ Does inadequate mixing result in excessive chemical use or insufficient coagulation to the extent that it impacts plant performance?
 - *A static mixer does not provide effective chemical mixing throughout the entire operating flow range of the plant.*
 - *Absence of a flash mixer results in less than optimal chemical addition and insufficient coagulation.*
- g. Flocculation
- ◆ Does a lack of flocculation time, inadequate equipment, or lack of multiple flocculation stages result in poor floc formation and degrade plant performance?
 - *A direct filtration plant, treating cold water and utilizing a flocculation basin with short detention time and hydraulic mixing, does not create adequate floc for filtration.*
- h. Sedimentation
- ◆ Does the sedimentation basin configuration or equipment cause inadequate solids removal that negatively impacts filter performance?
 - *The inlet and outlet configurations of the sedimentation basins cause short-circuiting, resulting in poor settling and floc carryover to the filters.*
 - *The outlet configuration causes floc break-up, resulting in poor filter performance*
 - *The surface area of the available sedimentation basins is inadequate, resulting in solids loss and inability to meet optimized performance criteria for the process.*
- i. Filtration
- ◆ Do filter or filter media characteristics limit the filtration process performance?
 - *The filter loading rate in a plant is excessive, resulting in poor filter performance.*
 - *Either the filter underdrain or support gravel have been damaged to the extent that filter performance is impacted.*
 - ◆ Do filter rate-of-flow control valves provide a consistent, controlled filtration rate?
 - *The rate-of-flow control valves produce erratic, inconsistent flow rates that result in turbidity and/or particle spikes.*
 - ◆ Do inadequate surface wash or backwash facilities limit the ability to clean the filter beds?
 - *The backwash pumps for a filtration system do not have sufficient capacity to adequately clean the filters during backwash.*
 - *The surface wash units are inadequate to properly clean the filter media.*
 - *Backwash rate is not sufficient to provide proper bed expansion to properly clean the filters.*
- j. Disinfection

-
- ◆ Do the disinfection facilities have limitations, such as inadequate detention time, improper mixing, feed rates, proportional feeds, or baffling, that contribute to poor disinfection?
 - *An unbaffled clearwell does not provide the necessary detention time to meet the Giardia inactivation requirements of the SWTR.*
 - k. Sludge/Backwash Water Treatment and Disposal
 - ◆ Do inadequate sludge or backwash water treatment facilities negatively influence plant performance?
 - *The plant is recycling backwash decant water without adequate treatment.*
 - *The plant is recycling backwash water intermittently with high volume pumps.*
 - *The effluent discharged from a sludge/backwash water storage lagoon does not meet applicable receiving stream permits.*
 - *Inadequate long-term sludge disposal exists at a plant, resulting in reduced cleaning of settling basins and recycle of solids back to the plant.*
 - 3. Plant Operability
 - a. Process Flexibility
 - ◆ Does the lack of flexibility to feed chemicals at desired process locations or the lack of flexibility to operate equipment or processes in an optimized mode limit the plant's ability to achieve desired performance goals?
 - *A plant does not have the flexibility to feed either a flocculant aid to enhance floc development and strength or a filter aid to improve filter performance.*
 - *A plant includes two sedimentation basins that can only be operated in series.*
 - b. Process Controllability
 - ◆ Do existing process controls or lack of specific controls limit the adjustment and control of a process over the desired operating range?
 - *Filter backwash control does not allow for the ramping up and down of the flow rate during a backwash event.*
 - *During a filter backwash, the lack of flow control through the plant causes hydraulic surging through the operating filters.*
 - *The level control system located in a filter influent channel causes the filter effluent control valves to overcompensate during flow rate changes in a plant.*
 - *Flows between parallel treatment units are not equal and cannot be controlled.*
 - *The plant influent pumps cannot be easily controlled or adjusted, necessitating automatic start-up/shutdown of raw water pumps.*
 - *Plant flow rate measurement is not adequate to allow accurate control of chemical feed rates.*
 - *Chemical feed rates are not easily changed or are not automatically changed to account for changes in plant flow rate.*
 - c. Process Instrumentation/Automation
 - ◆ Does the lack of process instrumentation or automation cause excessive operator time for process control and monitoring?
 - *A plant does not have continuous recording turbidimeters on each filter, resulting in extensive operator time for sampling.*
 - *The indication of plant flow rate is only located in the pipe gallery, which causes difficulty in coordinating plant operation and control.*
 - *Automatic shutdown/start-up of the plant results in poor unit process performance.*
 - d. Standby Units for Key Equipment
 - ◆ Does the lack of standby units for key equipment cause degraded process performance during breakdown or during necessary preventive maintenance activities?

-
- *Only one backwash pump is available to pump water to a backwash supply tank, and the combination of limited supply tank volume and an unreliable pump has caused staff to limit backwashing of filters during peak production periods.*
 - e. Flow Proportioning
 - ◆ Does inadequate flow splitting to parallel process units cause individual unit overloads that degrade process performance?
 - *Influent flow to a plant is hydraulically split to multiple treatment trains, and uneven flow distribution causes overloading of one flocculation/sedimentation train over the others.*
 - f. Alarm Systems
 - ◆ Does the absence or inadequacy of an alarm system for critical equipment or processes cause degraded process performance?
 - *A plant that is not staffed full-time does not have alarm and plant shut-down capability for critical finished water quality parameters (i.e., turbidity, chlorine residual).*
 - g. Alternate Power Source
 - ◆ Does the absence of an alternate power source cause reliability problems leading to degraded plant performance?
 - *A plant has frequent power outages, and resulting plant shutdowns and start-ups cause turbidity spikes in the filtered water.*
 - h. Laboratory Space and Equipment
 - ◆ Does the absence of an adequately equipped laboratory limit plant performance?
 - *A plant does not have an adequate process control laboratory for operators to perform key tests (i.e., turbidity, jar testing).*
 - i. Sample Taps
 - ◆ Does the lack of sample taps on process flow streams prevent needed information from being obtained to optimize performance?
 - *Filter-to-waste piping following plant filters does not include sample taps to measure the turbidity spike following backwash.*
 - *Sludge sample taps are not available on sedimentation basins to allow process control of the sludge draw-off from these units.*

C. Operation

1. Testing

a. Process Control Testing

- ◆ Does the absence or wrong type of process control testing cause improper operational control decisions to be made?
 - *Plant staff do not measure and record raw water pH, alkalinity, and turbidity on a routine basis; consequently, the impact of raw water quality on plant performance cannot be assessed.*
 - *Sedimentation basin effluent turbidity is not measured routinely in a plant.*

-
- b. Representative Sampling
 - ◆ Do monitoring results inaccurately represent plant performance or are samples collected improperly?
 - *Plant staff do not record the maximum turbidity spikes that occur during filter operation and following filter backwash events.*
 - *Turbidity sampling is not performed during periods when the reclaim backwash water pump is in operation.*
 - 2. Process Control
 - a. Time on the Job
 - ◆ Does staff's short time on the job and associated unfamiliarity with process control and plant needs result in inadequate or improper control adjustments?
 - *Utility staff, unfamiliar with surface water treatment, were given responsibility to start a new plant; and lack of experience and training contributed to improper coagulation control and poor performance.*
 - b. Water Treatment Understanding
 - ◆ Does the operator's lack of basic water treatment understanding contribute to improper operational decisions and poor plant performance or reliability?
 - *Plant staff do not have sufficient understanding of water treatment processes to make proper equipment or process adjustments.*
 - *Plant staff have limited exposure to water treatment terminology, limiting their ability to interpret information presented in training events or in published information.*
 - c. Application of Concepts and Testing to Process Control
 - ◆ Is the staff deficient in the application of their knowledge of water treatment and interpretation of process control testing such that improper process control adjustments are made?
 - *Plant staff do not perform jar testing to determine appropriate coagulant dosages for different water quality conditions.*
 - *Plant filters are placed back in service following backwash without consideration for effluent turbidity levels.*
 - *Filter to waste valves are available but are not used following filter backwash.*
 - *Plant staff do not calculate chemical dosages on a routine basis.*
 - *Plant staff do not change chemical feed systems to respond to changes in raw water quality.*
 - *Filters are backwashed based on time in service or headloss rather than on optimized performance goal for turbidity or particle removal.*
 - *Plant staff "bump" filters by increasing the hydraulic loading to see if backwashing is necessary.*
 - *Sedimentation basin performance is controlled by visual observation rather than process control testing.*
 - 3. Operational Resources
 - a. Training Program
 - ◆ Does inadequate training result in improper process control decisions by plant staff?
 - *A training program does not exist for new operators at a plant, resulting in inconsistent operator capabilities.*

b. Technical Guidance

- ◆ Does inappropriate information received from a technical resource (e.g., design engineer, equipment representative, regulator, peer) cause improper decisions or priorities to be implemented?
 - *A technical resource occasionally provides recommendations to the plant staff; however, recommendations are not based on plant-specific studies.*

c. Operational Guidelines/Procedures

- ◆ Does the lack of plant-specific operating guidelines and procedures result in inconsistent operational decisions that impact performance?
 - *The lack of operational procedures has caused inconsistent sampling between operator shifts and has led to improper data interpretation and process control adjustments.*

D. Maintenance

1. Maintenance Program

a. Preventive

- ◆ Does the absence or lack of an effective preventive maintenance program cause unnecessary equipment failures or excessive downtime that results in plant performance or reliability problems?
 - *Preventive maintenance is not performed on plant equipment as recommended by the manufacturer, resulting in premature equipment failures and degraded plant performance.*
 - *A work order system does not exist to identify and correct equipment that is functioning improperly.*

b. Corrective

- ◆ Does the lack of corrective maintenance procedures affect the completion of emergency equipment maintenance?
 - *A priority system does not exist on completion of corrective maintenance activities, resulting in a critical sedimentation basin being out of service for an extended period.*
 - *Inadequate critical spare parts are available at the plant, resulting in equipment downtime.*

c. Housekeeping

- ◆ Does a lack of good housekeeping procedures detract from the professional image of the water treatment plant?
 - *An unkempt, cluttered working environment in a plant does not support the overall good performance of the facility.*

2. Maintenance Resources

a. Materials and Equipment

- ◆ Does the lack of necessary materials and tools delay the response time to correct plant equipment problems?
 - *Inadequate tool resources at a plant results in increased delays in repairing equipment.*

b. Skills or Contract Services

- ◆ Do plant maintenance staff have inadequate skills to correct equipment problems or do the maintenance staff have limited access to contract maintenance services?
 - *Plant maintenance staff do not have instrumentation and control skills or access to contract services for these skills, resulting in the inability to correct malfunctioning filter rate control valves.*

Appendix F
Data Collection Forms

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A. Kick-Off Meeting Agenda

1. Purpose of the CPE

- Background on CCP process development and application
- Basis for conducting the CPE at the utility
- Assess ability of plant to meet optimized performance goals
 - Optimized performance criteria description
 - Multiple barrier concept for microbial protection
- Identify factors limiting plant performance
- Describe follow-up activities

2. Schedule CPE events

Utility Staff Involved

Date/Time

- Plant tour

- On-site data collection

Performance

Design

Operations

Maintenance

Administration

- Special studies

- Interviews

- Exit meeting

KICK-OFF MEETING

3. Information Resources

- Performance monitoring records
- Plant operating records
- As-built construction drawings
- Plant flow schematic
- As-built construction drawings
- O & M manuals
- Equipment manuals
- Previous and current year budgets
- Organizational structure
- Water rate structure

KICK-OFF MEETING

B. Attendance List

Utility Name _____

Date _____

[illegible]

ADMINISTRATION DATA

A. Name and Location

1. Name of Facility _____

2. Utility Name _____

3. Current Date _____

4. Contact Information:

	Administration	Plant	
Contact Name			
Title			
Mailing Address			
Phone			
Fax			

B. Organization

1. Governing Body (name and scheduled meetings)

2. Utility structure (attach organizational chart if available)

ADMINISTRATION DATA

3. Plant Organizational Structure (include operations, maintenance, laboratory personnel; attach chart if available)

C. Communications

1. Utility Mission Statement

2. Water Quality Goals

ADMINISTRATION DATA

3. Communication Mechanisms:

Type	Description
<input type="checkbox"/> Staff Meetings	
<input type="checkbox"/> Administrator/Board Visits to Plant	
<input type="checkbox"/> Reports (plant staff to manager; manager to governing board)	
<input type="checkbox"/> Public Relations/ Education	

D. Planning

1. Short-Term Needs

2. Long-Term Needs

ADMINISTRATION DATA**E. Personnel**

Title/Name	No.	Certification	Pay Scale	% Time at Plant
Comments (e.g., vacant positions, adequacy of current staffing):				

F. Plant Coverage

1. Shift Description (e.g., length, number per shift, weekend/holiday coverage)

2. Unstaffed Operation Safeguards (e.g., alarm/shutdown capability, dialer)

ADMINISTRATION DATA

G. Financial Information

1. Budget (basis for budget: total utility ☐ plant only ☐)

	Last Year Actual	Current Year Budget
Enter Year		
1. Beginning Cash on Hand		
2. Cash Receipts		
a. Water Sales Revenue		
b. Other Revenue (connection fees, interest)		
c. Total Water Revenue (2a + 2b)		
d. Number of Customer Accounts		
e. Average Charge per Account (2a ÷ 2d)		
3. Total Cash Available (1 + 2c)		
4. Operating Expenses		
a. Total O&M Expenses*		
b. Replacement Expenses		
c. Total O,M&R Expenses (4a + 4b)		
d. Total Loan Payments (interest + principal)		
e. Capital Purchases		
f. Total Cash Paid Out (4c + 4d + 4e)		
g. Ending Cash Position (3 - 4f)		
5. Operating Ratio (2a ÷ 4c) [±]		
6. Coverage Ratio (2c - 4c) ÷ (4d) [†]		
7. Year End Reserves (debt, capital improvements)		
8. End of Year Operating Cash (4g - 7)		
Source: USEPA Region 8 Financial Analysis Document (1997)		

* Includes employee compensation, chemicals, utilities, supplies, training, transportation, insurance, etc.

± Measure of whether operating revenues are sufficient to cover O,M&R expenses. An operating ratio of 1.0 is considered minimum for a self-supporting utility.

† Measure of the sufficiency of net operating profit to cover debt service requirements of the utility. Bonding requirements may require a minimum ratio (e.g., 1.25).

ADMINISTRATION DATA

2. Supporting Financial Information:

Category	Information
<input type="checkbox"/> Rate Structure <ul style="list-style-type: none"> • User fees • Connection fees • Planned rate changes 	
<input type="checkbox"/> Debt Service <ul style="list-style-type: none"> • Long-term debt • Reserve account 	
<input type="checkbox"/> Capital Improvements <ul style="list-style-type: none"> • Planning • Reserve account 	
<input type="checkbox"/> Budget Process <ul style="list-style-type: none"> • Staff involvement 	
<input type="checkbox"/> Spending Authorization <ul style="list-style-type: none"> • Administrator • Plant staff 	

DESIGN DATA

A. Plant Schematic and Capacity Information

1. Attach or draw plant flow schematic; include the following details:
 - Source water type/location
 - Major unit processes
 - Flow measurement locations
 - Chemical injection locations
 - Piping flexibility
 - On-line monitoring type/location

2. Flow Conditions:

Parameter	Flow	
Design Capacity		
Average Annual Flow		
Peak Instantaneous Flow		

DESIGN DATA

B. Major Unit Process Information

1. Flocculation:

Topic	Description	Information
1. Description	Type (reel, turbine, hydraulic)	
	Number trains/stages per train	
	Control (constant/variable speed)	
2. Dimensions	Length per stage:	
	Width per stage:	
	Depth per stage:	
	Total volume:	
3. Major Unit Process Evaluation	Selected Process Parameter(s):	
	Detention time (min)	
	Assigned process capacity	
4. Other Design Information (G values)		

Calculation of mixing energy as expressed by the mean velocity gradient (G) for mechanical mixing:

$$G = \left(\frac{P}{\mu v} \right)^{1/2}$$

G = Velocity gradient, sec⁻¹
 μ = viscosity, lb-sec/ft²
 v = volume, ft³
 P = energy dissipated, ft-lb/sec
 = hp x 550 ft-lb/sec/hp

Calculation of G for hydraulic mixing:

$$G = \left(\frac{\rho h_L}{\mu t} \right)^{1/2}$$

ρ = water density, 62.4 lb/ft³
 h_L = head loss, ft
 t = detention time, sec

Viscosity of Water Versus Temperature

Temp. (°F)	Temp. (°C)	Viscosity x 10 ⁻⁵ (lb-sec/ft ²)
32	0	3.746
40	4	3.229
50	10	2.735
60	16	2.359
70	21	2.050
80	27	1.799
90	32	1.595
100	38	1.424

DESIGN DATA

B. Major Unit Process Information (cont.)

2. Sedimentation:

Topic	Description	Information
1. Description	Type (conventional, tube settlers)	
	Number trains	
	Weir location	
	Sludge collection	
2. Dimensions	Length or diameter:	
	Width:	
	Depth:	
	Total surface area:	
3. Major Unit Process Evaluation	Selected Process Parameter(s):	
	Surface loading rate	
	Assigned process capacity	
4. Other Design Information		

DESIGN DATA

B. Major Unit Process Information (cont.)

3. Filtration:

Topic	Description	Information
1. Description	Type (mono, dual, mixed)	
	Number of filters	
	Filter control (constant, declining)	
	Surface wash type (rotary, fixed)	
2. Dimensions	Length or diameter:	
	Width:	
	Total surface area:	
3. Media design conditions (depth, effective size, uniformity coefficient):		
4. Backwash	Backwash initiation (headloss, turbidity, time):	
	Sequence (surface wash, air scour, flow ramping up/down, filter-to-waste):	

DESIGN DATA**B. Major Unit Process Information (cont.)**

3. Filtration (cont.):

Topic	Description	Information
5. Major Unit Process Evaluation	Selected Process Parameter(s);	
	Surface loading rate	
	Assigned process capacity	
6. Other Design Information		

DESIGN DATA

B. Major Unit Process Information (cont.)

4. Disinfection:

Topic	Description	Information
1. Description	Contact type (clearwell, storage)	
	T ₁₀ /T factor (see Table 4-4 or use tracer study results)	
2. Dimensions	Length or diameter:	
	Width:	
	Minimum operating depth:	
	Total volume:	
	Volume adjusted for T ₁₀ /T:	
3. Major Unit Process Evaluation	Selected Process Parameters:	
	Disinfectant (chlorine, chloramines)	
	Max. disinfectant residual (mg/L)	
	Maximum pH	
	Minimum temperature (°C)	
	Required <i>Giardia</i> inactivation	
	Required virus inactivation	
	Assigned process capacity	
5. Other Design Information		

C. Miscellaneous Equipment Information

1. Miscellaneous Equipment/Unit Processes:

Equipment/Process	Description/Information
1. Intake Structure <ul style="list-style-type: none"> • Location • Size of screen opening • Design limitations 	
2. Presedimentation <ul style="list-style-type: none"> • Detention time • Flexibility to bypass • Chemical feed capability • Design limitations 	
3. Rapid Mix <ul style="list-style-type: none"> • Type (mech., inline) • Chemical feed options • Mixing energy • Design limitations 	

C. Miscellaneous Equipment Information (cont.)

1. Miscellaneous Equipment/Unit Processes (cont.):

Equipment/Process	Description/Information
4. Backwash/Sludge Decant Treatment <ul style="list-style-type: none"> • Description • Recycle practices • Design limitations 	
5. Sludge Handling <ul style="list-style-type: none"> • Onsite storage volume • Long-term disposal • Design limitations 	

DESIGN DATA

C. Miscellaneous Equipment Information (cont.)

2. Chemical Feed Equipment:

Chemical Feed System	Capacity (mL/min)	Comments
<ul style="list-style-type: none"> Chemical name/characteristics (e.g., product density, strength) Purpose (e.g., coagulant, filter aid, T&O, disinfection) Number/type feed pumps 	<ul style="list-style-type: none"> Design Operating Range 	<ul style="list-style-type: none"> Dose control (e.g., flow paced) Manufacturer's information Calibration method Design issues
1.		
2.		
3.		
4.		
5.		
6.		

DESIGN DATA**C. Miscellaneous Equipment Information (cont.)**

3. Instrumentation:

On-Line Instrumentation <ul style="list-style-type: none">Type (e.g., turbidimeter, flow meter, particle counter, pH monitor, chlorine monitor)Manufacturer	Location <ul style="list-style-type: none">Process stream	Comments <ul style="list-style-type: none">CalibrationAlarm/shutdown capabilityDesign issues
1.		
2.		
3.		
4.		
5.		
6.		
7.		

DESIGN DATA**C. Miscellaneous Equipment Information (cont.)**

4. Pumping:

Flow Stream Pumped <ul style="list-style-type: none">• Location• Number of pumps• Rated capacity	Pump Type <ul style="list-style-type: none">• Turbine• Centrifugal	Comments <ul style="list-style-type: none">• Flow control method• Design issues• Source of rated capacity (name plate, specifications, flow meter)
1.		
2.		
3.		
4.		
5.		
6.		
7.		

A. Process Control Strategy and Communication

Describe the process control strategy used by the staff and associated communication mechanisms.

OPERATIONS DATA

Topic	Description/Information
1. Process Control Strategy <ul style="list-style-type: none"> Does the staff set specific performance targets? Are they posted? Who sets process control strategies and decisions? Are appropriate staff members involved in process control and optimization activities? 	
2. Communication Methods <ul style="list-style-type: none"> Does the staff have routine plant/shift meetings? How is communication conducted among operations, maintenance, and lab? Does the staff develop and follow operational procedures? 	

OPERATIONS DATA

B. Process Control Procedures

Describe specific process control procedures for the following available processes.

Process	Description/Information
1. Intake Structure <ul style="list-style-type: none"> • Flexibility to draw water from different locations & depths • Operational problems 	
2. Pumping/Flow Control <ul style="list-style-type: none"> • Flow measurement and control • Proportioning to multiple units • Operational problems 	
3. Presedimentation <ul style="list-style-type: none"> • Chemicals used/dose control • Monitoring (turbidity) • Sludge removal • Operational problems 	
4. Preoxidation <ul style="list-style-type: none"> • Chemicals used/dose control • Monitoring (residual) • Operational problems 	

OPERATIONS DATA

Describe specific process control procedures for the following available processes (cont.)

Process	Description/Information
5. Coagulation/Softening • Chemicals used/feed location • Dose control (adjustment for flow changes; adjustment for water quality - jar testing, streaming current, pilot filter) • Monitoring (turbidity, particle counting) • Operational problems	
6. Flocculation • Mixing energy adjustment • Use of flocculant aid • Monitoring • Operational problems	
7. Sedimentation • Performance objective/ monitoring (turbidity) • Sludge removal (control, adjustment) • Operational problems	

OPERATIONS DATA

Describe specific process control procedures for the following available processes (cont.)

Process	Description/Information
8. Filtration <ul style="list-style-type: none"> • Performance objective/ monitoring (turbidity, particles, headloss, run time) • Rate control due to demand, filter backwash • Use of filter aid polymer • Basis for backwash initiation (turbidity, particles, headloss, time) • Backwash procedures (wash sequence, duration and rates, basis for returning filter to service) • Filter/media inspections (frequency and type) • Operational problems 	
9. Disinfection <ul style="list-style-type: none"> • Performance objective/ monitoring (residual, CT) • CT factors (pH, minimum depth of contactor, T_{10}/T, maximum residual) • Operational problems 	

OPERATIONS DATA

Describe specific process control procedures for the following available processes (cont.)

Process	Description/Information
10. Stabilization <ul style="list-style-type: none"> • Chemical used/feed location • Performance objective/ monitoring (pH, index) • Operational problems 	
11. Decant Recycle <ul style="list-style-type: none"> • Duration, % of plant flow • Type of treatment (settling, chemical addition) • Operational problems 	
12. Sludge Treatment	

OPERATIONS DATA

C. Data Management

Describe data collection and management approaches and tools used by plant staff.

Topic	Description/Information
1. Data Collection <ul style="list-style-type: none">Type of forms used (water quality testing, shift rounds, plant log)Computer (SCADA, database)	
2. Data Application <ul style="list-style-type: none">Development of daily, monthly reportsDevelopment of trend charts	

D. Problem Solving and Optimization Activities

Describe specific approaches and tools used to solve problems or optimize plant processes.

Topic	Description/Information
1. Problem Solving/Optimization <ul style="list-style-type: none">Use of special studiesPilot plantList recent and ongoing problem solving/optimization activitiesAvailable resources (technical assistance providers, training, manuals of practice)	

OPERATIONS DATA**E. Complacency and Reliability**

Describe specific approaches used to address complacency and reliability issues in the plant.

Topic	Description/Information
<div>1. Complacency</div> <ul style="list-style-type: none">• How does staff respond to unusual water quality conditions?• Does staff have an emergency response plan? How does staff train for unusual conditions or events? <div>2. Reliability</div> <ul style="list-style-type: none">• Does staff capability to make process control decisions exist at more than one level?	

OPERATIONS DATA

F. Laboratory Capability

1. Describe available analytical testing capability.

Analytical Capability	Capability ✓	Description/Comments
• Color		
• Jar test		
• Particle counting		
• pH		
• Solids (dissolved)		
• Taste and odor		
• Temperature		
• Turbidity		
• Aluminum		
• Calcium		
• Fluoride		
• Hardness		
• Iron		
• Magnesium		
• Manganese		
• Sodium		
• Alkalinity		
• Ammonia Nitrogen		
• Nitrite/nitrate		
• Phosphate		
• Sulfate		
• Chlorine residual		
• Bacteriological		
• Disinfection byproducts		

OPERATIONS DATA

2. Describe laboratory space/equipment and procedures.

Process	Description/Information
Lab Space and Equipment <ul style="list-style-type: none"> • Does adequate lab space exist? • Do adequate equipment and facilities exist? 	
Lab Procedures <ul style="list-style-type: none"> • Is testing conducted following standard procedures? • Where is lab data recorded? • Describe quality control procedures. 	
Equipment Calibration <ul style="list-style-type: none"> • Describe procedure for calibrating turbidimeters. • Describe procedures for calibrating other equipment (continuous chlorine and pH monitors). 	

MAINTENANCE DATA

A. Maintenance Program

Describe the plant maintenance program.

Topic	Description/Information
1. Preventive Maintenance <ul style="list-style-type: none">Describe equipment inventory method (cards, computer).Describe maintenance scheduling method (daily, weekly, monthly, annual).	
2. Corrective Maintenance <ul style="list-style-type: none">Describe the work order system (issuing orders/documentation).Describe priority setting (relationship to process control and plant performance needs).List major equipment out of service within last 6 months.	
3. Predictive Maintenance <ul style="list-style-type: none">Describe methods used to predict maintenance needs (vibration, infrared analysis).	
4. Housekeeping <ul style="list-style-type: none">Does poor housekeeping detract from plant performance/image?	

MAINTENANCE DATA

B. Maintenance Resources

Describe the available maintenance resources at the plant.

Topic	Description/Information
1. Equipment Repair and Parts <ul style="list-style-type: none"> • Are critical spare parts stored at the plant? • Can vendors provide quick response to spare parts needs? • What is the policy on parts procurement by staff? 	
2. Maintenance Expertise <ul style="list-style-type: none"> • Describe staff expertise (mechanical, electrical, instrumentation). • Does the staff use any contract maintenance services? How responsive are they to needs? • Does staff develop and use maintenance procedures? 	
3. Work Space and Tools <ul style="list-style-type: none"> • Does the plant have adequate work space and tools to perform maintenance tasks? 	
4. Performance Monitoring <ul style="list-style-type: none"> • How is maintenance performance measured (time to complete task, work order backlog)? 	

FIELD EVALUATION DATA

A. Historical Water Production Data

1. Use the following table to determine the peak instantaneous operating flow for the plant.

Month/Year	Maximum Daily Flow	Operating Time Per Day	Flow During Operation ⁽¹⁾	Instantaneous Peak Flow ⁽²⁾

⁽¹⁾ If a plant operates less than 24 hr/day, flow during operation can be determined from the equation below:

$$Q_A = \frac{Q_T}{T} \times \frac{24 \text{ hr}}{\text{day}}$$

Q_A = Average flow during operation

Q_T = Total flow in 24-hour period

T = Time of plant operation, hours

⁽²⁾ Peak instantaneous flow through a plant is often different than the average flow due to changing water demands that the plant must meet. The peak instantaneous flow during a day can sometimes be obtained from plant logs (e.g., raw pump operation, rate change time and flow).

FIELD EVALUATION DATA

B. Water Usage

- Determine the water usage per capita based on water production records and population served. Water usage statistics for the United States are shown in the table below.

$$Q_C = \frac{Q_T}{P}$$

Q_C = Usage per capita per day
 Q_T = Total flow in 24-hour period
 P = Population served

Population _____

Q_C Avg. _____

Q_C Peak _____

State	Use (gpcpd)	State	Use (gpcpd)
Alabama	191	Nebraska	174
Alaska	134	Nevada	306
Arizona	191	New Hampshire	85
Arkansas	154	New Jersey	131
California	175	New Mexico	184
Colorado	188	New York	166
Connecticut	120	North Carolina	107
Delaware	124	North Dakota	114
Florida	146	Ohio	127
Georgia	160	Oklahoma	173
Hawaii	180	Oregon	164
Idaho	163	Pennsylvania	128
Illinois	154	Rhode Island	115
Indiana	115	South Carolina	148
Iowa	131	South Dakota	121
Kansas	144	Tennessee	148
Kentucky	128	Texas	176
Louisiana	147	Utah	255
Maine	81	Vermont	80
Maryland	165	Virginia	119
Massachusetts	119	Washington	217
Michigan	136	West Virginia	96
Minnesota	105	Wisconsin	118
Mississippi	127	Wyoming	188
Missouri	131	Puerto Rico	115
Montana	164	Virgin Islands	63

Source: Solley, W.B. Preliminary Estimates of Water Use in the United States, 1995, U.S. Geological Survey (1997).

FIELD EVALUATION DATA

2. Determine unaccounted for water based on monthly or annual water production and meter records. Unaccounted for water typically varies from 10 to 12 percent for new systems and 15 to 30 percent for older systems (Metcalf and Eddy, Inc. 1991).

$$Q_{\%} = \frac{(Q_T - Q_M)}{Q_T} \times 100$$

$Q_{\%}$ = % unaccounted

Q_T = Total plant water production for month or year

Q_M = Total metered water for month or year

Q_T _____

Q_M _____

$Q_{\%}$ _____

3. Determine backwash water percent based on volume of water filtered and volume of water used for backwash. Typically, the amount of water used for backwash ranges for 2 to 6 percent for conventional plants. Higher percentages can occur for direct filtration plants.

$$BW_{\%} = \frac{(V_F - V_{BW})}{V_F} \times 100$$

$BW_{\%}$ = % backwash water

V_F = Volume of water filtered

V_{BW} = Volume of water used for backwash

V_F _____

V_{BW} _____

$BW_{\%}$ _____

FIELD EVALUATION DATA

C. In-Plant Studies

Describe results of in-plant studies conducted during the CPE.

Topic	Description/Information/Findings
1. Filter Media Evaluation <ul style="list-style-type: none"> • Check media depth and type. • Check media condition (presence of chemicals/debris, mudballs, worn media). • Check support gravel level (variation of less than 2 inches acceptable). 	
2. Backwash Evaluation <ul style="list-style-type: none"> • Check backwash rate (measure rise rate in the filter versus time and convert to backwash rate; > 15 gpm/ft² acceptable). • Check bed expansion > 20 percent acceptable). 	

FIELD EVALUATION DATA

C. In-Plant Studies (cont.)

Describe results of in-plant studies conducted during the CPE.

Topic	Description/Information/Findings
2. Backwash Evaluation (cont.) • Observe backwash procedure (flow distribution, ramping of flow rate, turbidity of water at end of backwash).	
3. Coagulant Dosage Evaluation • Verify reported dose with actual; measure liquid or dry feed rate (lb/min, mL/min) and convert to dose (mg/L).	
4. Turbidity Meter Evaluation • Check meter calibration or compare with calibrated meter.	

FIELD EVALUATION DATA

C. In-Plant Studies (cont.)

Describe results of in-plant studies conducted during the CPE.

Topic	Description/Information/Findings

A. Interview Guidelines

The following interview guidelines are provided to assist CPE providers with the interview process.

1. **Conduct interviews with one staff person at a time in a private location.**

- It is important to create a comfortable environment for the interview process to take place. Confidentiality of the interview should be explained.

2. **Keep the interview team size small.**

- The number of people included on each interview team should be kept to a minimum (e.g., 1 to 3) to avoid overwhelming the person being interviewed. If more than one person is included on the team, one person should be assigned as the lead interviewer.

3. **Allow 30 to 45 minutes for each interview.**

- Interview times will vary depending on the personality of the individual being interviewed and the number and type of issues involved. It is the responsibility of the interviewer to maintain the focus on performance-related issues. Interviews can easily be detracted by individuals who find an “open ear” for presenting grievances.

4. **Explain the purpose of the interview and use of the information.**

- It is important for the people being interviewed to understand that any information obtained from this process is only used to support identification of factors limiting performance (i.e., areas impacting performance). The interview information is not used to place blame on specific individuals or departments.

5. **Conduct interviews after sufficient information has been gathered from CPE activities.**

- Utilize results and observations gained from the plant tour, performance assessment, major unit process evaluation, and data collection activities to identify areas of emphasis during the interviews.

6. **Progress through the interview in a logical order.**

- For example, if an administrator is being interviewed, focus questions on administrative support, then on design issues, followed by operation and maintenance capabilities.

7. **Ask relevant questions with respect to staff area of involvement.**

- For example, when interviewing maintenance personnel, ask questions related to relevant topics such as maintenance responsibilities, communication with supervisors, and administrative support for equipment.

8. **Ask open-ended questions.**

- For example, a question such as “Are you aware of any design deficiencies with the current plant?” would provide better information than a question like “Do you think that the flocculation basin provides sufficient detention time for flocculation?”.

INTERVIEW DATA

9. **Ask the questions; don't give the answers.**

- The purpose of the interview is to gain the perspective of the person being interviewed. Ask the question and wait for the response (i.e., don't answer your own question based on information you may have received from previous activities). Rephrasing the question may sometimes be necessary to provide clarity.

10. **Repeat a response to a question for clarification or confirmation.**

- For example, the interviewer can confirm a response by stating, "If I understand you correctly, you believe that the reason for poor plant performance during April was due to excessive algae growth in the source water."

11. **Avoid accusatory statements.**

- Accusatory statements will likely lead to defensiveness by the person being interviewed. Rather, if an area of concern is suspected, ask questions that can confirm or clarify the situation.

12. **Use the interview to clarify or confirm field information.**

- For example, if performance problems occurred during one month of the past year, ask questions to clarify the perceived reasons for these problems.

13. **Note specific responses that support factor identification.**

- During or following the interview, the interviewer may want to note or underline specific responses that support the identification of possible factors limiting performance. This summary can then be used during team debriefing and factor identification meetings.

INTERVIEW DATA

B. Personnel Interview Form

Name _____ Title _____

Time at plant _____ Years of experience _____

Education/training/certification _____

Interview notes (concerns, recommendations in administration, design, operation, and maintenance):

[illegible]

EXIT MEETING

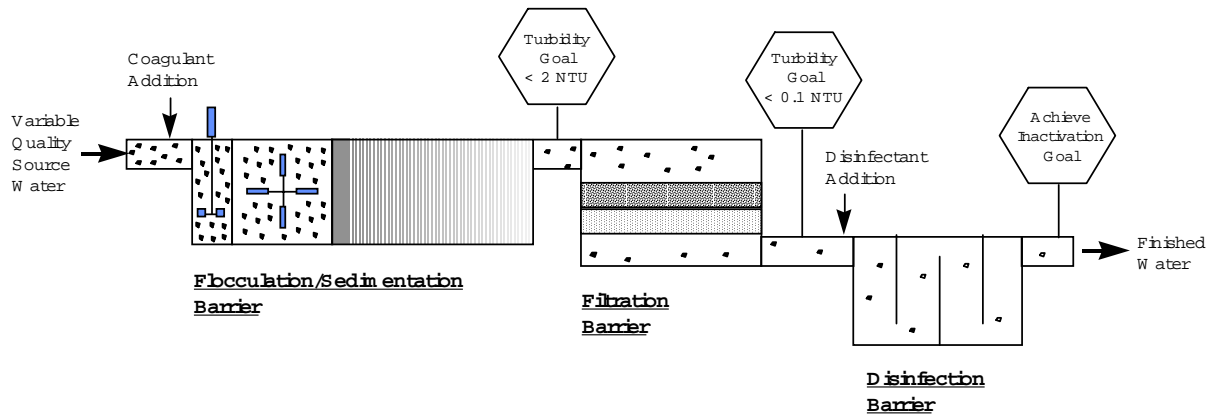
A. Attendance List

Utility Name _____

Date _____

[illegible]

B. Multiple Barrier Concept for Microbial Contaminant Protection



- Given a variable quality source water, the treatment objective is to produce a consistent, high quality finished water.
- Protozoan parasites, such as *Giardia* and *Cryptosporidium*, are found in most source waters; however, it is difficult to quantify their presence and assess their viability.
- Microbial pathogens in the source water, such as protozoan parasites, bacteria, and viruses, can be physically removed as particles in treatment processes and inactivated through disinfection.
- Multiple barriers are provided in a treatment plant to remove or inactivate microbial pathogens.
- Key treatment barriers include flocculation/sedimentation, filtration, and disinfection.
- Since measurement of protozoan parasites is difficult, surrogate parameters, such as turbidity, particle counting, and pathogen inactivation, are used to assess the performance of each barrier.

C. Optimization Performance Criteria

A summary of performance criteria for surface water treatment plants to provide protection against microbial contaminants is presented below:

1. Minimum Data Monitoring Requirements

- Daily raw water turbidity
- Settled water turbidity at 4-hour time increments from each sedimentation basin
- On-line (continuous) turbidity from each filter
- One filter backwash profile each month from each filter

2. Individual Sedimentation Basin Performance Criteria

- Settled water turbidity less than 1 NTU 95 percent of the time when annual average raw water turbidity is less than or equal to 10 NTU
- Settled water turbidity less than 2 NTU 95 percent of the time when annual average raw water turbidity is greater than 10 NTU

3. Individual Filter Performance Criteria

- Filtered water turbidity less than 0.1 NTU 95 percent of the time (excluding 15-minute period following backwashes) based on the maximum values recorded during 4-hour time increments
- Maximum filtered water measurement of 0.3 NTU
- Initiate filter backwash immediately after turbidity breakthrough has been observed and before effluent turbidity exceeds 0.1 NTU.
- Maximum filtered water turbidity following backwash of 0.3 NTU
- Maximum backwash recovery period of 15 minutes (i.e., return to less than 0.1 NTU)
- Maximum filtered water measurement of less than 10 particles (in the 3 to 18 μm range) per milliliter (if particle counters are available)

4. Disinfection Performance Criteria

- CT values to achieve required log inactivation of *Giardia* and virus

Appendix G
Example CPE Report

**Results of the
Comprehensive Performance Evaluation
of Water Treatment Plant No. 005**

Prepared by:

Prepared for:

Site Visit Information

Mailing Address:

Date of Site Visit:

Utility Personnel:

CPE Team:

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Introduction

The Composite Correction Program (CCP) (1) is an approach developed by the U. S. Environmental Protection Agency and Process Applications, Inc. to improve surface water treatment plant performance and to achieve compliance with the Surface Water Treatment Rule (SWTR). Its development was initiated by Process Applications, Inc. and the State of Montana (2), who identified the need for a program to deal with performance problems at their surface-supplied facilities. The approach consists of two components, a Comprehensive Performance Evaluation (CPE) and Comprehensive Technical Assistance (CTA).

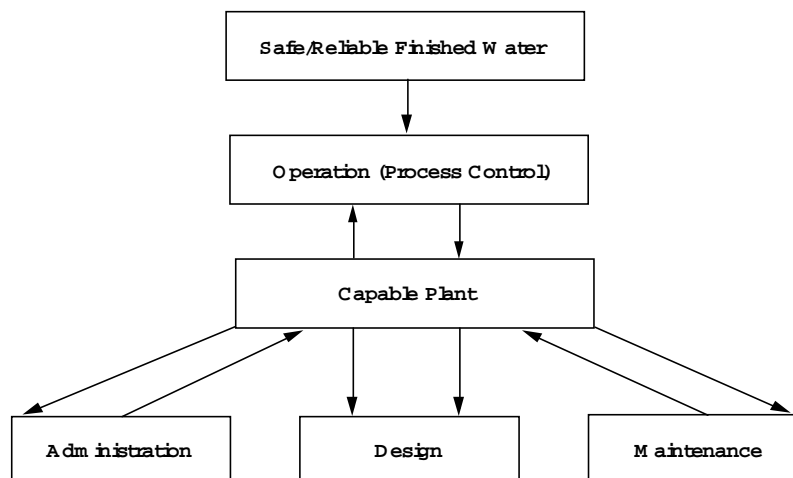
The methodology followed during a CPE is described in Figure 1. A comprehensive assessment of the unit process design, administration and maintenance support is performed to establish whether a capable plant exists. Additionally, an assessment is made on the plant staff's ability to apply process control principles to a capable plant to meet the overall objective of providing safe and reliable finished water. The results of this assessment approach establish the plant capability and a prioritized set of factors limiting performance. Utility staff can address all or some of the identified factors, and improved performance can occur as the result of these efforts. A CTA is used to improve performance of an existing plant when challenging or difficult-to-address factors are identified during the CPE. Therefore, the CCP approach can be utilized to evaluate the ability of a

water filtration plant to meet the turbidity and disinfection requirement of the SWTR and then to facilitate the achievement of cost effective compliance.

In recent years, the CCP has gained prominence as a mechanism that can be used to assist in optimizing the performance of existing surface water treatment plants to levels of performance that exceed the requirements in the SWTR. The current standards do not always adequately protect against some pathogenic microorganisms, as evidenced by recent waterborne disease outbreaks. Producing a finished water with a turbidity of <0.1 NTU provides much better protection against pathogens like *Cryptosporidium* (3,4,5, 6,7,8,9,10,11), the microorganism responsible for a large outbreak of *Cryptosporidiosis* in Milwaukee in April 1993, where 403,000 people became ill and at least 79 people died.

USEPA has chosen to use the CCP approach to evaluate selected surface water treatment plants in this region. Water Treatment Plant No. 005 was selected as the first candidate for a CPE. This plant has experienced difficulties with continuously meeting the turbidity requirements of the SWTR, and the water system manager and staff expressed interest in receiving assistance with correcting this situation.

FIGURE 1. Comprehensive Performance Evaluation methodology.



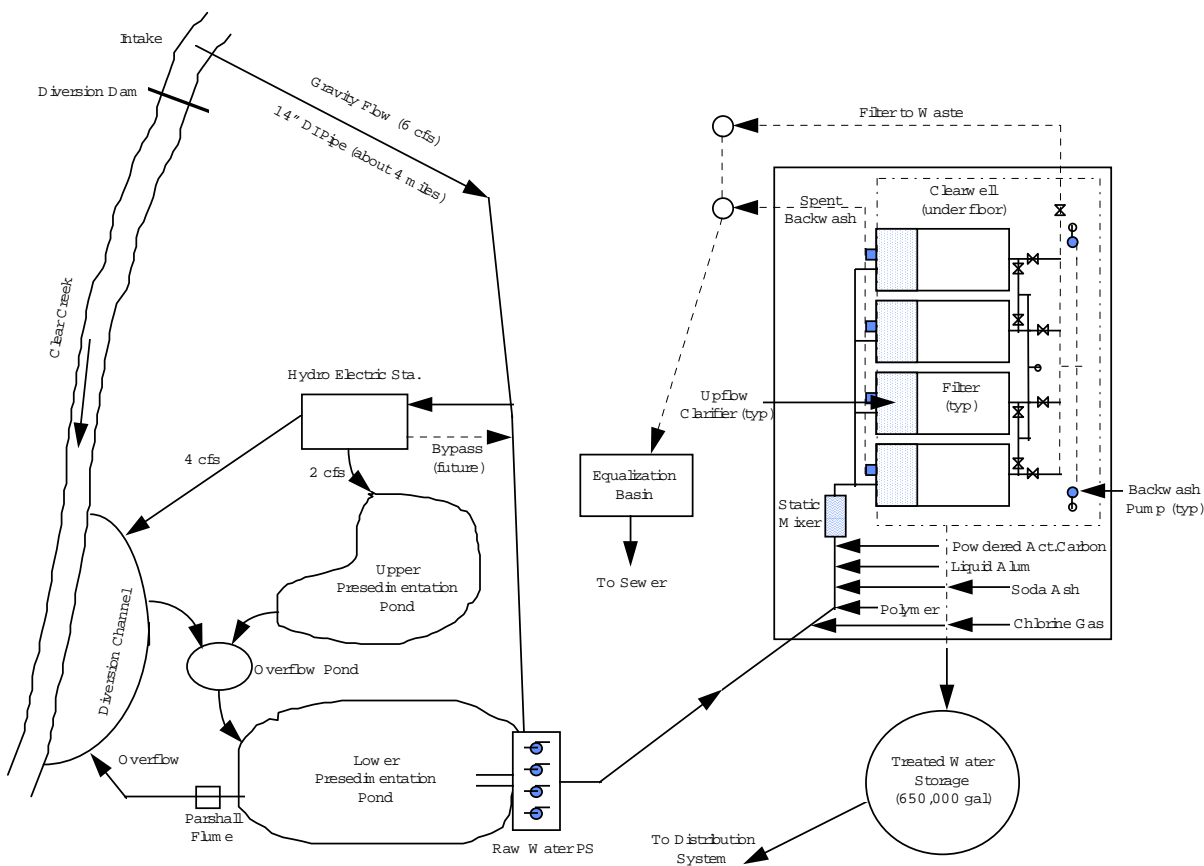
The following report documents the findings of the CPE conducted at Water Treatment Plant No. 005. The CPE identifies and prioritizes the reasons for less-than-optimum performance. The CPE may be followed by the second phase of the CCP, Comprehensive Technical Assistance (CTA), if appropriate.

Facility Information

A flow schematic of Water Treatment Plant No. 005 is shown in Figure 2. The water source for the plant is Clear Creek. Staff reported that turbidity in the creek reaches a maximum level of 50 - 80 NTU. The Clear Creek Basin can be characterized as mountainous and forested. Sources of potential contamination include wildlife and human sources (e.g., recreation use, camping etc.).

The intake for the treatment plant is located in Clear Creek upstream of a small diversion dam. The turbidity in the raw water pipeline has not been recorded regularly since the treatment plant began operation. Limited raw water pipeline turbidity data from before plant start-up was reviewed during the CPE. The data indicate that turbidity in the raw water pipeline was typically low (i.e., < 1.5 NTU) with some peaks in the spring that were less than 5 NTU. About 100 cubic yards of sediment is dredged and removed at two-year intervals in the vicinity of the intake, upstream of the diversion dam. Settling of particulates at this location may partially account for the low raw water turbidity values observed. The utility is also constructing a dam upstream of the intake; and, as a result, even less raw water turbidity variations are expected in the future.

FIGURE 2. Water treatment flow schematic.



About 6 cfs of water flows by gravity from the intake through about four miles of 14-inch diameter ductile iron pipe to a utility-owned hydroelectric power

generating station near the water treatment plant. After the hydroelectric station, about 4 cfs flows back into Clear Creek and the remaining 2 cfs flows

through two large presedimentation ponds. Detention time through these ponds is estimated to be about 14 days. A raw water pump station located beside the lower pond includes four constant speed raw water pumps, each with a 700 gpm capacity.

The amount of water that can be run through the presedimentation ponds and discharged to the creek is limited by the capacity of the Parshall flume on the overflow of the lower pond. Also, there are no provisions to bypass an individual pond to reduce the detention time. The ponds can be bypassed by directing the raw water to the pump station intake; however, this results in the bypassing of the hydroelectric station. The utility is planning to install another pipeline from the hydroelectric station to the raw water pumping station before the spring runoff occurs. This will allow the ponds to be bypassed without interfering with the hydroelectric station operation.

The water treatment plant began operation in August 1996. Prior to that, chlorination was provided after the settling ponds before entering the distribution system. The plant has a reported firm design capacity of about 3 MGD. Major treatment components include chemical feed equipment, four package treatment trains consisting of an upflow clarifier and filter basins, a 110,000 gallon clearwell, and a 600,000 gallon finished water storage tank. Each of the upflow clarifier and filter units has a reported capacity of 1 MGD. The plant is designed to operate at 1 MGD incremental flow rates with one raw water pump dedicated to each treatment train in operation. Unique characteristics of the plant are summarized as follows.

- Large presedimentation ponds prior to treatment.
- Static mixer for coagulant mixing.
- Chemical feed capability: alum, polymer, soda ash, powdered activated carbon, chlorine.
- Upflow clarifiers with gravel media (1 to 5 mm size).
- Mixed media filters.
- Filter-to-waste capability set by a common control valve to 1 MGD. (NOTE: This flow rate is not easily adjusted and limits the flexibility to change the individual treatment train flow rate to a value other than 1 MGD.)
- Two continuously monitoring particle counters on filter effluent (one shared by two trains).

- Clearwell with intra-basin baffles

Performance Assessment

During the CPE, the capability of the Water Treatment Plant No. 005 was evaluated to assess whether the facility, under existing conditions, could comply with the turbidity and disinfection requirements that are used to define optimized performance. Optimized performance, for purposes of this CPE, represents performance criteria that exceeds the SWTR requirements. Optimized performance would require that the facility take a source water of variable quality and consistently produce a high quality finished water. Multiple treatment processes (e.g., flocculation, sedimentation, filtration, disinfection) are provided in series to remove particles, including microbial pathogens, and provide disinfection to inactivate any remaining pathogens.

Water Treatment Plant No. 005 utilizes a package water treatment process that includes combined flocculation/sedimentation in an upflow clarifier and filtration. Each of the available processes represents a barrier to prevent the passage of microbial pathogens through the plant. By providing multiple barriers, any microorganisms passing one process can be removed in the next, minimizing the likelihood of microorganisms passing through the entire treatment system and surviving in water supplied to the public. The role of the water treatment operator is to optimize the treatment processes (i.e., barriers) under all conditions because even temporary loss of a barrier could result in the passage of microorganisms into the distribution system and represents a potential health risk to the community.

A major component of the CPE process is an assessment of past and present performance of the plant. This performance assessment is intended to identify if specific unit treatment

processes are providing multiple barrier protection through optimum performance. The performance assessment is based on data from plant records and data collected during special studies performed during the CPE.

Specific turbidity performance targets were used during this assessment. These specific performance targets include:

- Sedimentation - turbidity of less than 1 NTU 95 percent of the time, since average annual raw water turbidity is less than 10 NTU.
- Filtration - individual filter turbidity less than 0.1 NTU 95 percent of the time (excluding 15-minute period following backwash); also, maximum filtered water turbidity following backwash of 0.3 NTU.
- Disinfection - CT values to achieve required log *Giardia* cyst and virus inactivation.

A plant influent turbidimeter and strip chart recorder are provided, but the plant operators do not routinely record daily influent water turbidity in their operating log. The plant influent turbidity strip charts for the past year were reviewed during the evaluation. A frequency analysis of these data is summarized in

Table 1. As indicated, the raw water turbidity is less than or equal to 4 NTU 95 percent of the time. Maximum daily plant influent turbidity varied from less than 1 NTU to 10 NTU, as shown in Figure 3.

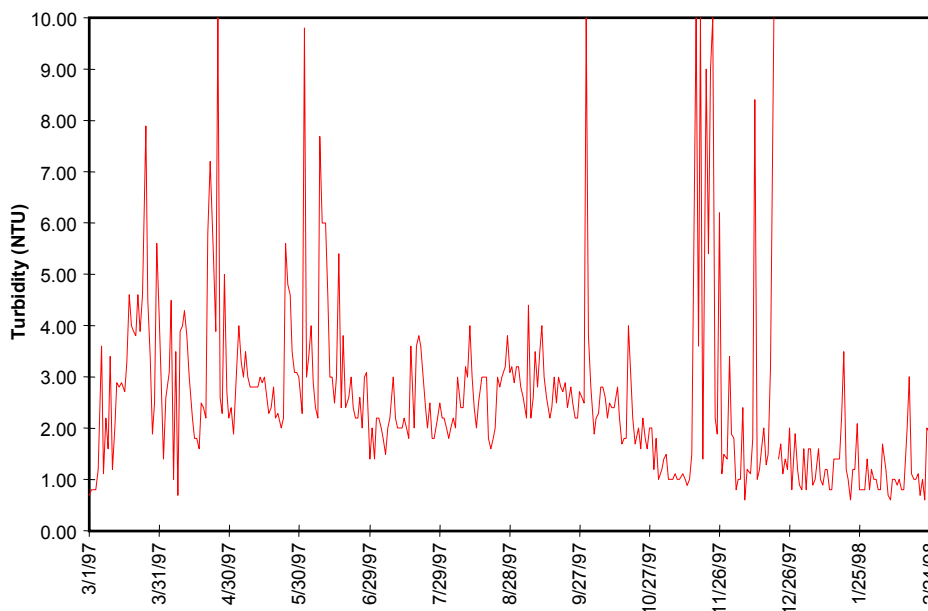
TABLE 1. Frequency Analysis of Raw Water Turbidity

Percentile	Raw Water NTU*
50	2.2
75	3.0
90	3.6
95	4.0
Average	2.6

*Daily maximum value

The turbidimeter is located a long distance from the influent pipe. A significant number of brief (a few minutes to less than 1 hour) turbidity spikes were noted on the strip chart. A special study would be required to determine the cause of these brief influent turbidity spikes. Influent turbidity during the CPE was less than 1 NTU.

FIGURE 3. Daily maximum plant influent water turbidity.



The finished water turbidimeter is located at the outlet of the 600,000 gallon finished water storage tank. This meter has a strip chart recorder, and operators routinely record this data for water quality reporting purposes.

The plant operators do not routinely sample and measure turbidity after the upflow clarifiers. During the CPE, turbidities of 0.56 to 0.71 NTU were measured between the upflow clarifier and the filter over a two-hour period. During the same period the plant influent turbidity ranged from 0.5 to 0.7 except for a 15-minute spike from 3 to 10 NTU after a brief filter shutdown. Because of the low influent water turbidity conditions during the CPE and the lack of historical turbidity data at the clarifier outlet, the ability of the plant to meet the 1 NTU turbidity goal on a long-term basis could not be determined.

The plant does not have on-line turbidimeters for monitoring turbidity following individual filters, and plant operators do not routinely collect grab samples to measure turbidity at this location. Two on-line particle counters are available for monitoring filter performance; however, staff have experienced operating problems with at least one of the units. To assess historical plant performance, turbidity values from after the treated water storage tank were used.

The daily maximum finished water turbidity for the previous 12 months is shown in Figure 4. The results of a frequency analysis of the finished water data are shown in Table 2 and indicate that 95 percent of the time the filtered water turbidity was less than 0.87 NTU.

During several months, plant performance did not meet the turbidity requirement of the SWTR (i.e., <0.50 NTU 95 percent of the time on monthly basis). From April through June, filtered water turbidity consistently exceeded the regulated limit of 0.50 NTU. Plant staff reported that this period of poor performance was due to a bad batch of alum and poor water quality from the ponds. A large amount of algae or other filamentous material from the ponds caused clogging problems on the media support screens of the upflow clarifiers for several weeks. This material was cleaned manually with great difficulty, and during the worst period cleaning was required on a daily frequency. Hand-cleaned screens have been installed on the raw water pump intakes in the lower pond to assist with removing this material before it reaches the treatment units. It is also possible that post flocculation may have occurred in the clearwell and finished water storage tank during this period.

FIGURE 4. Daily maximum finished water turbidity.

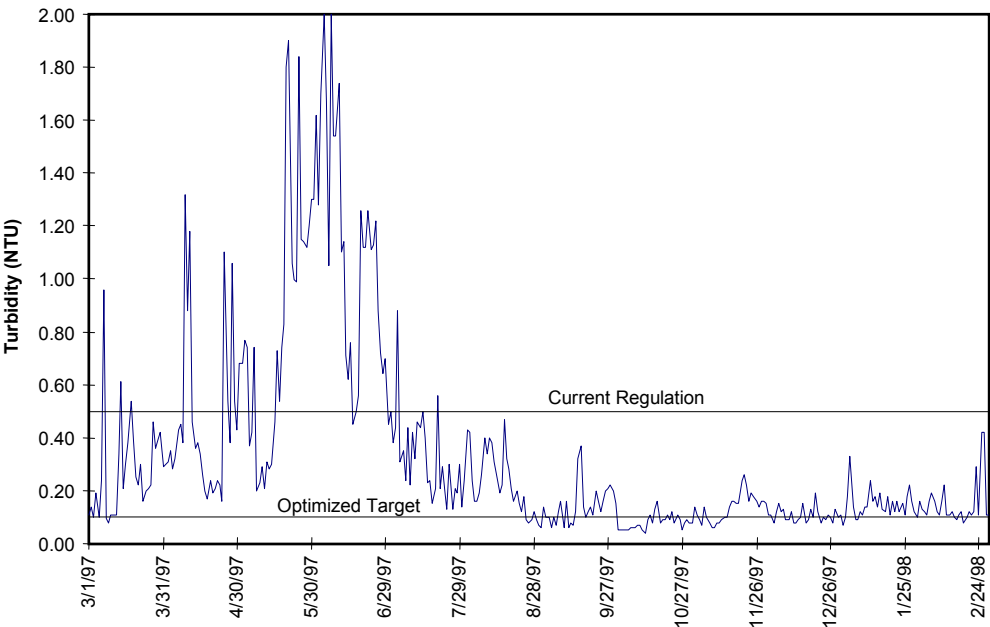


TABLE 2. Frequency Analysis of Finished Water Turbidity

Percentile	Finished Water NTU*
------------	---------------------

50	0.16
75	0.32
90	0.55
95	0.87
Average	0.33

*Daily maximum value

Although significant improvement in performance has recently occurred, the plant did not achieve the optimized filtered water turbidity target of less than 0.1 NTU during the past year. This performance allows an increased opportunity for pathogens, such as *Cryptosporidium* oocysts, to pass into the public water supply.

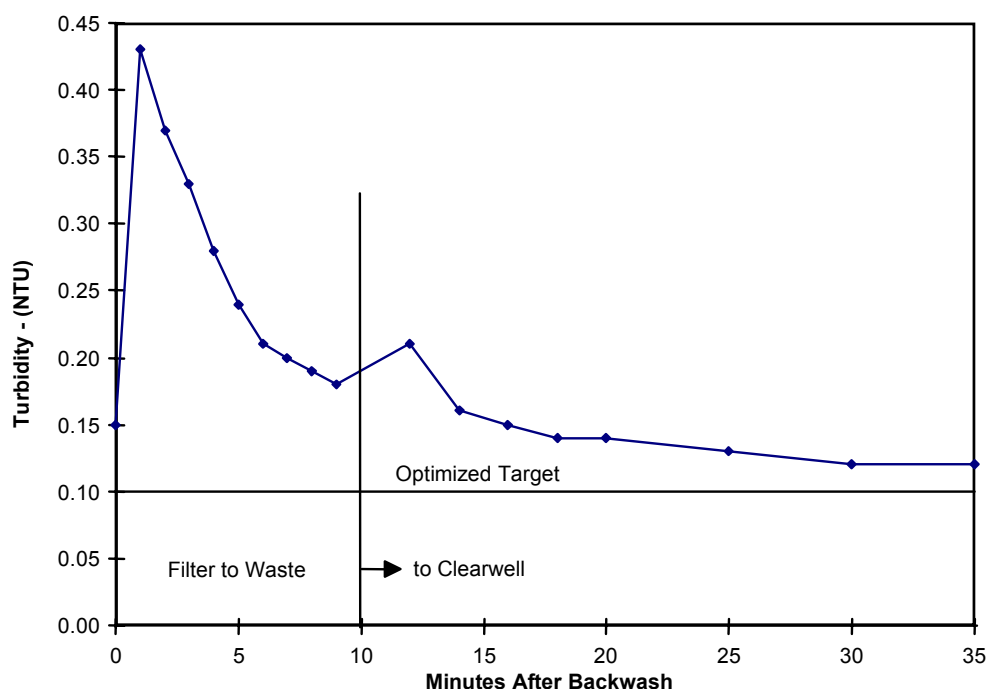
During the CPE a special study was conducted on the filter media, backwash procedure, and performance of a filter following a backwash. Prior to backwashing, filter unit #2 was drained to allow physical observation of the filter media. The total depth of the mixed media was consistently about 31.5 inches. Of this mixed media depth, about 18

inches was anthracite. Inspection of the media at and below the surface showed that the media was very clean. During the backwash, a filter bed expansion of 21.8 percent was calculated, which is within the acceptable range of 20 to 25%.

Immediately after completion of the filter backwash, the filtered water turbidity was measured periodically for about 35 minutes. These data are shown in Figure 5. The current procedure is to filter to waste for ten minutes after the end of the backwash cycle. As indicated by the performance graph, the filter did not meet the backwash optimization criteria of a maximum turbidity spike of 0.3 NTU and return to less than 0.1 NTU within 15 minutes.

In summary, performance data for the last year show that Water Treatment Plant No. 005 has not been in compliance with the SWTR on a consistent basis. In addition, the plant has not met the optimized performance goal of 0.1 NTU for filtered water. Consequently, this performance assessment indicates that the water system is at risk of passing microbial pathogens to consumers.

FIGURE 5. Filter effluent turbidity profile after backwash.



Major Unit Process Evaluation

Major unit processes were assessed with respect to their capability to provide consistent performance and

an effective barrier to passage of microorganisms on a continuous basis. The performance goal used in this assessment for the filtration process was a settled water turbidity of less than 2 NTU and a

filtered water turbidity of less than 0.1 NTU. Capabilities of the disinfection system were based on the USEPA guidance manual (12) requirements for inactivation of *Giardia* and viruses.

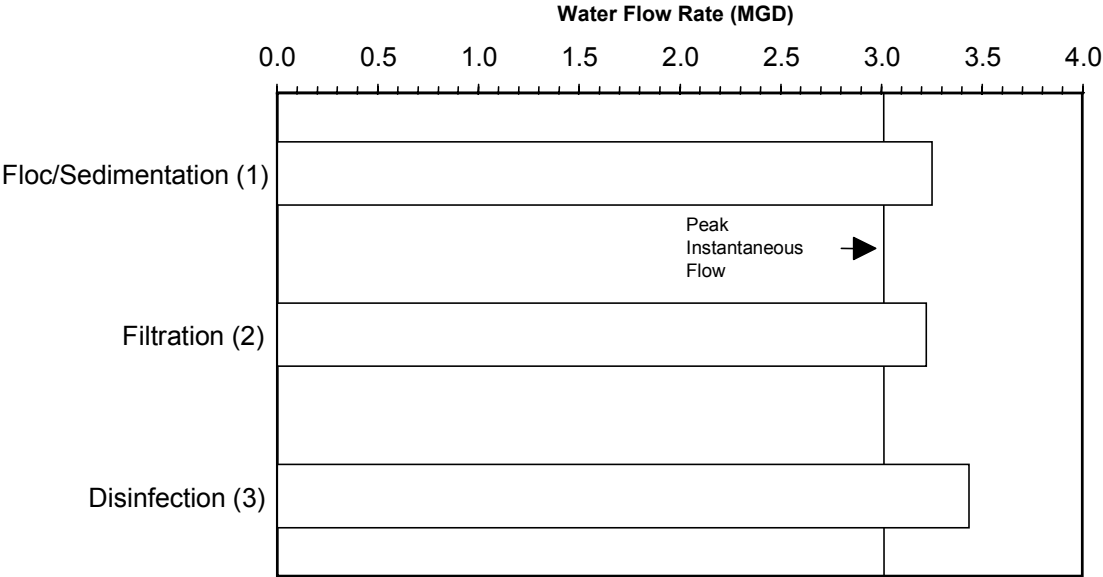
Since the plant's treatment processes must provide an effective barrier at all times, a peak instantaneous operating flow is typically determined. The peak instantaneous operating flow represents the maximum flow rate that the unit processes are subjected to, which represents the hydraulic conditions where the treatment processes are the most vulnerable to the passage of microorganisms. If the treatment processes are adequate at the peak instantaneous flow, then the major unit processes are projected to be capable of providing the necessary effective barriers at lower flow rates.

Water Treatment Plant No. 005 has a maximum raw water pumping capacity of 4 MGD. The plant was designed for a maximum treatment capacity of 3 MGD with one treatment unit out of service. A peak

instantaneous flow rate of 3 MGD is used for the major unit process evaluation, based on the highest instantaneous flow rate reported by the staff.

Major unit process capability was assessed by projecting treatment capacity of each major unit process against the peak instantaneous flow rate. The major unit process evaluation for the entire treatment plant is shown in Figure 6. The unit processes evaluated are shown on the left side of the graphs, and the flow rates against which the processes were assessed are shown across the top. Horizontal bars on the graph represent the projected peak capability of each unit process to achieve the desired optimized process performance. These capabilities were projected based on the combination of treatment processes at the plant, the CPE team's experience with other similar processes, industry guidelines, and regulatory standards. The shortest bar represents the unit process which limits plant capability the most relative to achieving the desired plant performance.

FIGURE 6. Major unit process evaluation.



- (1) Surface area = 280 ft²; rated at 8.0 gpm/ft², upflow clarifier with rock gravel media
- (2) Surface area = 560 ft²; rated at 4 gpm/ft²; mixed media
- (3) Volume = 98,000 gal; total 3-log *Giardia* inactivation/removal required; assume 2.5-log removal allowed through conventional plant credit and 0.5-log required by disinfection; pH = 7.5; temp = 0.5°C; chlorine residual = 1.6 mg/L; T₁₀/T = 0.7; 3 ft minimum clearwell depth

The major unit processes evaluated were the upflow clarifiers (flocculation and sedimentation), filtration, and disinfection processes. Criteria used to assess each major unit process are described in the notes below the graph.

The upflow clarifiers were rated based on their surface overflow rate. Typically, conventional sedimentation basin capability is rated based on a surface overflow rate of 0.5 to 0.7 gpm/ft². A surface overflow rate of 10 gpm/ft² is used by the package plant manufacturer for the design rating of their upflow clarifier units. Because of the combined

flocculation and sedimentation function and the short detention time of these units, they were rated based on an overflow rate of 8 gpm/ft². This produced a combined flocculation/sedimentation capability rating of 3.23 MGD when using all four treatment units.

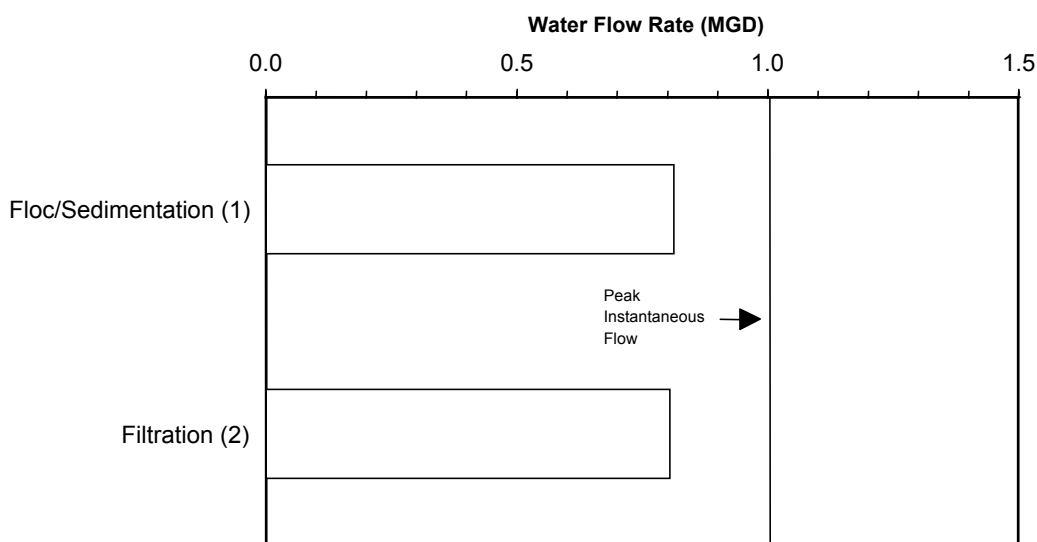
The filtration process was rated based on a loading rate of 4 gpm/ft² and use of all four filters. These criteria resulted in a combined filtration capability of 3.23 MGD.

The disinfection process was assessed based on USEPA Surface Water Treatment Rule requirements for inactivation of 3-log of *Giardia* cysts and 4 log of viruses. The *Giardia* removal/inactivation is the most stringent criteria; consequently, it was used as the basis of the disinfection evaluation. A well-operated conventional filtration plant is allowed a 2.5-log removal credit for *Giardia* cysts, and the remaining 0.5-log removal is achieved by meeting specified CT requirements associated with chemical disinfection. CT is the disinfectant concentration (C) in mg/L multiplied by the time (T) in minutes that the water is in

contact with the disinfectant. The required CT value was obtained from the USEPA guidance manual (3), using typical plant values for free chlorine residual (i.e., 1.0 mg/L) and pH (i.e., 7.5) and a worst case water temperature of 0.5°C. The volume of the clearwell was adjusted for the minimum operating depth of 3 feet. A T₁₀/T ratio of 0.70 was used because of the superior baffling conditions in the clearwell. Under this scenario, the disinfection process is capable of treating 3.44 MGD, using a required free chlorine CT value of 46 mg/L-min.

The results of the major unit process evaluation indicate that the plant should be capable of treating the peak instantaneous flow rate of about 3.2 MGD with four treatment trains in service (i.e., 0.8 MGD per train). However, the control of the plant is set up so that each treatment train operates at a constant flow rate of 1 MGD (see Figure 7), and flexibility does not exist to easily operate each train at lower flow rates without modifying the filter to waste piping from the filters.

FIGURE 7. Process evaluation for individual treatment unit.



(1) Surface area = 70 ft²; rated at 8.0 gpm/ft²; upflow clarifier with gravel media

(2) Surface area = 140 ft²; rated at 4 gpm/ft²; mixed media

The major unit process evaluation indicates that the current practice of operating individual treatment units at a constant flow rate of 1 MGD, as required by the design and control system, may be contributing to the less-than-optimum performance of the flocculation/sedimentation and filtration processes.

The areas of design, operation, maintenance, and administration were evaluated in order to identify factors which limit performance. These evaluations were based on information obtained from the plant tour, interviews, performance and design assessments, special studies, and the judgment of the evaluation team. Each of the factors was classified as A, B, or C according to the following guidelines:

Performance Limiting Factors

-
- A — Major effect on a long term, repetitive basis
- B — Minimal effect on a routine basis or major effect on a periodic basis
- C — Minor effect

The A and B factors were prioritized as to their relative impact on performance and are summarized below. In developing this list of factors limiting performance, 50 potential factors were reviewed; and their impact on the performance of Water Treatment Plant No. 005 was assessed. The evaluation team identified six factors that are limiting plant performance. Numerous other factors were not felt to be affecting plant performance. The factors and the findings that support their selection are summarized below in prioritized order.

Alarms (Design) A

- The plant does not have alarm and shutdown capability on chlorine feed, chlorine residual, influent turbidity and finished water turbidity.

Process Flexibility (Design) A

- Inability to automatically change the filter to waste flow rate to values other than 1 MGD. (NOTE: This lack of flexibility limits the flow rate of the individual treatment trains, since the plant flow rate must be 1 MGD to match the filter to waste flow rate of 1 MGD; otherwise, the water level in a filter changes.)
- No ability to feed filter aid polymer to the filters. (NOTE: This flexibility can be used to enhance filter performance, especially during times when clarifier performance is less than optimum.)
- Inability to gradually increase and decrease backwash flow rate. (NOTE: This flexibility provides better cleaning of the filter media, less opportunity for loss of media, and better re-stratification of the media following backwash.)

Policies (Administration) A

- Lack of established performance goals for the plant, such as 0.1 NTU filtered water turbidity, that would provide maximum public health protection and associated support to achieve these performance goals.

Insufficient Time on the Job (Operation) A

- No sampling and evaluation of upflow clarifier performance.
- Inadequate testing to optimize coagulant type and dosages. (NOTE: Some jar testing was completed by staff; however, standard testing procedures were not followed to determine optimum dosages.)
- No monitoring of individual filter turbidity.
- Excessive caution on use of the creek source to achieve optimized performance.
- Starting “dirty” filters without backwashing or using filter to waste.
- Non-optimized feed point for flocculant aid addition. (NOTE: Flocculant aid products are typically fed at a location with gentle mixing to avoid breaking the long-chain organic molecules.)

Process Instrumentation/Automation (Design) B

- No turbidimeters are located on individual filters and creek source (i.e., at turbine).
- Plant is designed to automatically start and stop operation based on storage tank level and upflow clarifier backwash requirements. (NOTE: Without initiating a filter backwash or the filter to waste mode after each shutdown, the potential exists to pass trapped particles (i.e., potential pathogens) through the plant due to hydraulic surging.)
- Location of influent turbidity sample line relative to the monitor cell may cause inaccurate readings.

Presedimentation (Design) B

- Long detention time and subsequent low turnover contributes to excessive algae growth and poor water quality.
- Lack of flexibility to operate one, or portion of one, presedimentation pond to reduce detention time and increase turnover.
- Lack of flexibility to bypass ponds without bypassing the turbine. (NOTE: A new bypass is under construction which will provide this flexibility.)

- Limited ability to maintain high turnover through ponds when not in use because of restriction in Parshall flume from pond 2 to creek.

Evaluation Follow-Up

The potential exists to achieve optimized performance goals and, therefore, enhance public health protection with Water Treatment Plant No. 005. Implementation of a Comprehensive Technical Assistance (CTA) project by a qualified facilitator has been demonstrated to be an effective approach to achieve optimum performance goals (13). Through a CTA project, the performance limiting factors identified during the Comprehensive Performance Evaluation would be addressed in a systematic manner. A partial list of potential CTA activities that could be implemented by a facilitator and plant staff is presented below:

- Facilitate development of optimization performance goals by the city administration to provide adequate direction and support to operation and maintenance staff.
- Establish a process control program based on prioritized data collection, database development, data and trend interpretation, and process adjustments.
- Provide technical guidance on use of the creek source versus the presedimentation ponds during seasonal water quality changes.
- Facilitate special studies with plant staff to assist them with optimizing plant performance and establishing the need for minor plant modifications.
- Provide training to assist operators with optimizing coagulant type and dosages.

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Appendix H
Example CPE Scheduling Letter

April 6, 1998

Chairman/Mayor/Public Works Director
Water Authority/City/Town

RE: Evaluation of the _____ Water Authority/City/Town Water Treatment Plant
May 18 - 21, 1998

Dear Mr./Ms. _____:

You were recently contacted by _____ of the _____ (regulatory agency) regarding an evaluation of your water treatment facility. This letter is intended to provide you with some information on the evaluation and describe the activities in which the _____ Water Authority/City/Town will be involved. The evaluation procedure that will be used at your facility is part of an overall water treatment optimization approach called the Composite Correction Program.

The Composite Correction Program (CCP) was developed by the U. S. Environmental Protection Agency and Process Applications, Inc. to optimize surface water treatment plant performance for protection against microbial contaminants such as *Giardia* and *Cryptosporidium*. The approach consists of two components, a Comprehensive Performance Evaluation (CPE) and Comprehensive Technical Assistance (CTA). The first component, the Comprehensive Performance Evaluation, will be conducted at your facility the week of . During the CPE, all aspects of your water treatment administration, design, operation, and maintenance will be reviewed and evaluated with respect to their impact on achieving optimized performance.

The evaluation will begin with a brief entrance meeting on Monday, May 18, 1998 at approximately 2:00 P.M. The purpose of the entrance meeting is to discuss with the plant staff and administrators the purpose of the evaluation and the types of activities occurring during the next three days. Any questions and concerns regarding the evaluation can also be raised at this time. It is important that the plant administrators and those persons responsible for plant budgeting and planning be present because this evaluation will include an assessment of these aspects of the plant. Following the entrance meeting, which should last approximately 30 minutes, the plant staff will be requested to take the evaluation team on an extensive plant tour. After the plant tour, the team will begin collecting performance and design data. Please make arrangements so that the monitoring records for the previous 12 months, operating records, and any design information for the plant are available for the team. Also, a continuous recording on-line turbidimeter will be installed on one or more of your filters. Sample taps to accomodate this connection should be available.

On Tuesday, the evaluation team will be involved in several different activities. The major involvement of the plant staff will be responding to the evaluation team's questions on plant performance and operation and maintenance practices. Several special studies may also be completed by the team to investigate the performance capabilities of the plant's different unit treatment processes. Requests to inspect filter media and monitor filter backwashes will be coordinated with staff to minimize the impact on plant operation.

Also on Tuesday, a member of the evaluation team will meet with the administrators to review the administrative policies and procedures and financial records associated with the plant. We would like to review your water treatment budget for the previous and current fiscal years. We would expect that most of this information would be available in your existing accounting system.

April 6, 1998
Page 2

We request that the plant staff and administrators be available for interviews either Tuesday afternoon or Wednesday morning. We will be flexible in scheduling these interviews around other required duties of you and your staff. Each of the interviews will require about 30 to 45 minutes of time.

We are anticipating that an exit meeting will be held on Thursday morning at 8:30 A.M., and it will last about 1 hour. During the exit meeting, the results of the evaluation will be discussed with all of those who participated. The performance capabilities of the treatment processes will be presented, and any factors found to limit the performance of the plant will be discussed. The evaluation team will also answer any questions regarding the results of the evaluation. The results presented in the exit meeting will form the basis of the final report, which will be completed in about one month.

We look forward to conducting the CPE at your facility. If you have any questions prior to the evaluation, please don't hesitate to contact us.

Very truly yours,

Evaluation Team Contact

Appendix I
Example Special Study

Example Special Study

(as developed by CTA facilitator and plant staff prior to implementation)

- I. Hypothesis
 - A. Increasing the ferric chloride dosage for low turbidity water (< 5.0 NTU) will improve the finished water turbidity and increase plant stability.
 - B. Increasing the ferric dosage may decrease alkalinity below level to maintain finished water pH target.
- II. Approach
 - A. Conduct series of jar tests using established jar testing guidelines that vary ferric chloride dosages (start with 0.5 mg/L increments and bracket down to 0.1 mg/L).
 - B. Add filter aid at the end of the flocculation time to simulate plant dosage (up to 0.1 mg/L).
 - C. Measure pH, alkalinity, temperature and turbidity of raw and finished water.
 - D. Document and interpret test results.
 - E. Test optimum dosage at full plant scale (pilot mode where filtered water is directed to waste).
 - F. Measure same parameters as above.
 - G. If results indicate alkalinity limitation is necessary (finished water alkalinity < 20 mg/L), conduct jar tests with soda ash addition.
- III. Duration of Study
 - A. Two weeks to complete jar and full-scale testing.
- IV. Expected Results
 - A. Improved finished water turbidity and increased plant stability at higher ferric chloride dosages.
 - B. Deficiency in finished water alkalinity.
 - C. Loss of finished water pH.
 - D. Potential change in primary coagulant.
 - E. Potential need for alkalinity (soda ash) addition.
- V. Conclusions
 - A. To be compiled in summary report after completion of study.
- VI. Implementation
 - A. To be determined after completion of study.

Appendix J
Example Operational Guideline

Example Operational Guideline

Subject: Process Control Data Collection
Objective: To establish a data collection method

Number: 5
Date Adopted: 4/29/97
Date Revised:

- I. Measure and record the following water quality, chemical usage, and flow data at the frequency noted.
 - A. Raw water parameters (measure/record once per day):
 1. Plant flow rate - MGD (8:00 a.m. to 8:00 a.m.)
 2. Raw turbidity - 7 days per week
 3. pH - units - 7 days per week
 4. Alkalinity - mg/L - 5 days per week
 5. Temperature - °C - 7 days per week
 - B. Chemical usage data (record once per day):
 1. Coagulant use - gal/day
 2. Coagulant batch density - lb/gal
 3. Filter aid use - gal/day
 4. Filter aid batch density - lb/gal
 5. Chlorine use - lb/day
 6. Orthophosphate use - lb/day
 - C. Finished water parameters (measure/record once per day, unless noted otherwise):
 1. Alkalinity - mg/L - 5 days per week
 2. pH - 7 days per week
 3. Free chlorine residual - mg/L - 7 days per week (minimum value for day from chart)
 4. Turbidity - NTU - value at established 4-hour increments
- II. Individual sedimentation basin turbidity.
 - A. Collect samples once each 4-hour period from the effluent of each basin and use lab turbidimeter to measure turbidity.
- III. Individual filter monitoring data collection methods.
 - A. Circular recording charts will be used for turbidity monitoring.
 1. Individual turbidity charts are located on top of the individual turbidity monitors.
 2. Twenty-four hour charts will be used.
 3. When changing charts, record the "change chart time" for the 24-hour period.
 - B. Data to record from individual filter charts.
 1. Start of all backwashes (note time and record on chart).
 2. Return to service after all backwashes (note time and record on chart).
 3. Backwash turbidity spike (highest turbidity value after filter is back on-line).
 4. Recovery turbidity (turbidity 15 minutes after filter placed back in service).
 5. Highest turbidity recorded every 4 hours for each individual filter, excluding backwash spike and recovery turbidities.

Process Control Data Collection (Continued)

- IV. Utilize the process control data entry form below for data recording.
- A. Complete the data entry form once per day, 7 days per week.
 - B. Enter daily data into computer database program and print out daily report.
 - C. At the end of each month, print monthly process control report from the database program and distribute as follows:
 1. Public Works Director
 2. Monthly process control file in filing cabinet
 3. Post copy on plant bulletin board

Water Treatment Plant Process Control Data Entry Form							
Parameter	Units	Data	Parameter	Units	Data		
Date	m/d/y		Filter aid batch density	lb/gal			
Flow rate	MGD		Other chemical use	gal/day			
Raw turbidity	NTU		Other chemical density	lb/day			
Raw pH	units		Finished alkalinity	mg/L			
Raw alkalinity	mg/L		Finished pH	units			
Raw temperature	C		Finished free chlorine	mg/L			
Coagulant daily use	gal/day		<i>Giardia</i> Inact. target	log			
Coag. batch density	lb/gal		Chlorine use	lb/day			
Filter aid daily use	gal/day		Orthophosphate use	lb/day			
Turbidity Data	Time	2400-0400	0400-0800	0800-1200	1200-1600	1600-2000	2000-2400
Max. Sedimentation 1	NTU						
Max. Sedimentation 2	NTU						
Max. filter 1 turbidity	NTU						
Max. filter 2 turbidity	NTU						
Max. filter 3 turbidity	NTU						
Max. filter 4 turbidity	NTU						
Finished turbidity	NTU						
Post Backwash Data	Filter No.	1	2	3	4		
BW turbidity spike	NTU						
Turb. 15 min. on-line	NTU						

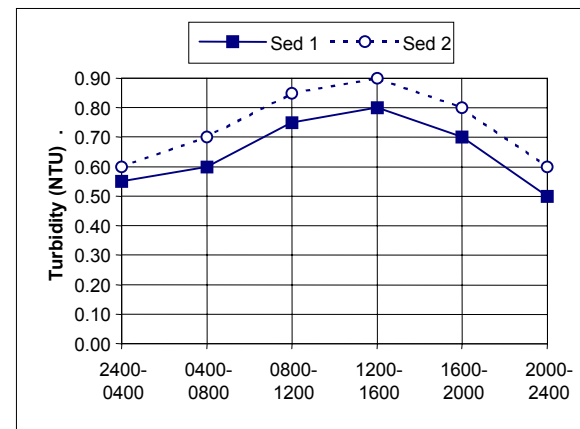
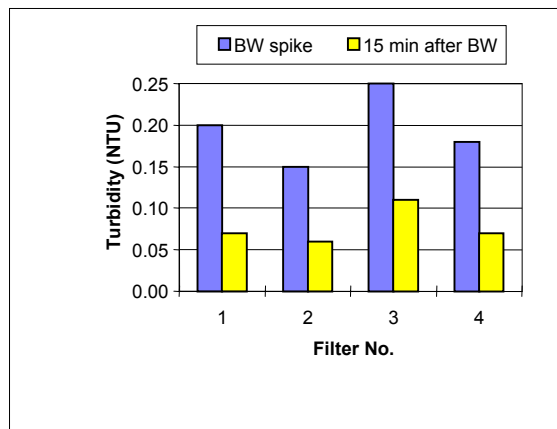
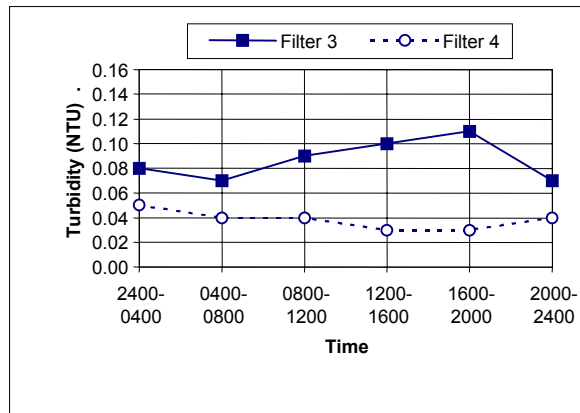
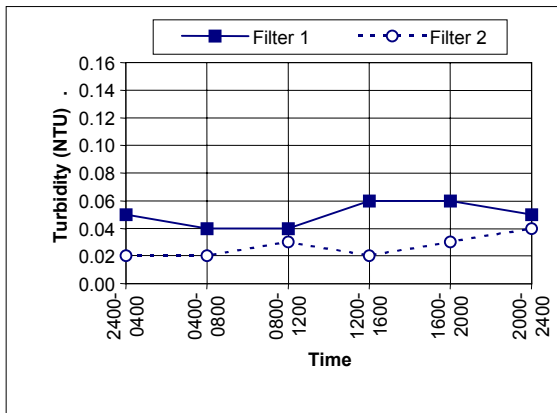
Appendix K
Example Process Control Daily Report

Water Treatment Plant Process Control Daily Report
28-Feb-98

Parameter	Units	Data	Parameter	Units	Data		
Date	m/d/y	2/28/98	Filter aid batch density	lb/gal	0.3		
Flow rate	MGD	1.00	Other chemical use	gal/day	0.000		
Raw turbidity	NTU	5.00	Other chemical density	lb/day	0.0		
Raw pH	units	7.5	Finished alkalinity	mg/L	30.0		
Raw alkalinity	mg/L	34.0	Finished pH	units	7.2		
Raw temperature	C	5.0	Finished free chlorine	mg/L	1.0		
Coagulant daily use	gal/day	13.0	<i>Giardia</i> Inact. target	log	1.0		
Coag. batch density	lb/gal	3.36	Chlorine use	lb/day	12.0		
Filter aid daily use	gal/day	2.00	Orthophosphate use	lb/day	16.0		
Turbidity Data	Time	2400-0400	0400-0800	0800-1200	1200-1600	1600-2000	2000-2400
Max. Sedimentation 1	NTU	0.55	0.60	0.75	0.80	0.70	0.50
Max. Sedimentation 2	NTU	0.60	0.70	0.85	0.90	0.80	0.60
Max. filter 1 turbidity	NTU	0.05	0.04	0.04	0.06	0.06	0.05
Max. filter 2 turbidity	NTU	0.02	0.02	0.03	0.02	0.03	0.04
Max. filter 3 turbidity	NTU	0.08	0.07	0.09	0.10	0.11	0.07
Max. filter 4 turbidity	NTU	0.05	0.04	0.04	0.03	0.03	0.04
Finished turbidity	NTU	0.04	0.04	0.05	0.06	0.06	0.05
Post Backwash Data	Filter No.	1	2	3	4		
BW turbidity spike	NTU	0.20	0.15	0.25	0.18		
Turb. 15 min. on-line	NTU	0.07	0.06	0.11	0.07		

Calculated Parameters

Coagulant dose	mg/L	5.24	Required CT	mg/L-min	57.2	
Filter aid dose	mg/L	0.060	Measured CT	mg/L-min	103.7	
Other chemical dose	mg/L	0.00	CT ratio		1.8	
Chemical cost	\$/m gal	47.91				



Appendix L
Example Jar Test Guideline

JAR TEST PROCEDURE (page 1)

TEST CONDITIONS

Facility	Date	Time	Turbidity	Temperature	pH	Alkalinity	
Water Source		Coagulant		Coagulant Aid			

PREPARING STOCK SOLUTIONS

Step 1 Select desired stock solution concentration (see Table 1).
Choose a stock solution concentration that will be practical for transferring chemicals to jars.

Table 1		
Stock Solution (%)	Concentration (mg/L)	mg/L dosage per mL of stock solution added to 2 liter jar
0.01	100	0.05
0.05	500	0.25
0.1	1,000	0.5
0.2	2,000	1.0
0.5	5,000	2.5
1.0	10,000	5.0
1.5	15,000	7.5
2.0	20,000	10.0

Desired Stock Solution (%)	Coagulant	Coag. Aid	

Step 2 Determine chemical amount to add to 1 liter flask.
If using dry products, see Table 2. If using liquid products, go to step 3.

Table 2		
Stock Solution (%)	Conc. (mg/L)	mg of alum added to 1 liter flask
0.01	100	100
0.05	500	500
0.1	1,000	1,000
0.2	2,000	2,000
0.5	5,000	5,000
1.0	10,000	10,000
1.5	15,000	15,000
2.0	20,000	20,000

Desired Amount in 1 liter flask (mL)	Coagulant	Coag. Aid	

Step 3 Determine liquid chemical amount to add to volumetric flask.
For liquid chemicals, use the equation below -

$$\text{mL coagulant} = \frac{(\text{stock solution } \%) \times (\text{flask volume, mL}) \times (8.34 \text{ lb/gal})}{100 \times (\text{chemical strength, lb/gal})}$$

	Coagulant	Polymer	
Chemical Strength (lb/gal) ¹			
Stock Solution Volume (mL)			
Desired Volume of Chemical to add to Flask (mL)			

¹ Note: Chemical Strength = chemical density x % strength

JAR TEST PROCEDURE (page 2)

JAR SETUP

Set up individual jar doses based on desired range of test.

Determine amount of stock solution by dividing dose by mg/L per mL (see Table 1).

Coagulant - Jar #	1	2	3	4	5	6	
Dose (mg/L)							
Stock Solution (mL)							
Coagulant Aid - Jar #	1	2	3	4	5	6	
Dose (mg/L)							
Stock Solution (mL)							
	1	2	3	4	5	6	
Dose (mg/L)							
Stock Solution (mL)							

TEST PROCEDURE

Step 1

Set rapid mix time equal to rapid mix detention time.

To determine rapid mix time, use the following equation -

$$\text{Rapid mix time (min)} = \frac{(\text{rapid mix volume, gal}) \times (1,440 \text{ min/day}) \times (60 \text{ sec/min})}{(\text{plant flow rate, gal/d})}$$

Mix Volume (gal)	
Plant Flow Rate (gal/day)	
Mix Time (sec)	

Step 2

Set total flocculation time equal to total flocculation detention time in plant.

To determine total flocculation time, use the following equation -

$$\text{Floc time (min)} = \frac{(\text{flocculator volume, gal}) \times (1,440 \text{ min/day})}{(\text{plant flow rate, gal/d})}$$

Floc Volume (gal)			
Floc Time (min)			

Step 3

Use Figure 1 to determine the jar mixing energy values (rpm) that correspond to the approximate flocculator mixing energy values (G). Flocculator mixing energy can be estimated from plant design information (O&M manual) or can be calculated from the equation described in Appendix F - B.1. Flocculation.

Flocculator Stage	1st	2nd	3rd	
Flocculator Mixing (G)				
Jar Mixing (rpm)				

Step 4

Set sample time based on particle settling velocity. Use the equation below to determine sample time when using 2 liter gator jars as described in Figure 1.

$$\text{Sample time (min)} = \frac{(10 \text{ cm}) \times (\text{surface area, ft}^2) \times (1,440 \text{ min/day}) \times (7.48 \text{ gal/ft}^3)}{(\text{plant flow rate, gal/d}) \times (30.48 \text{ cm/ft})}$$

Sedimentation Surface Area (ft ²)	
Plant Flow Rate (gal/day)	
Sample Time (min)	

JAR TEST PROCEDURE (page 3)

TEST RESULTS

Record test results in the table below.

	1	2	3	4	5	6	
Settled Turbidity (NTU)							
Settled pH							
Filtered Turbidity (NTU)							

Comments:

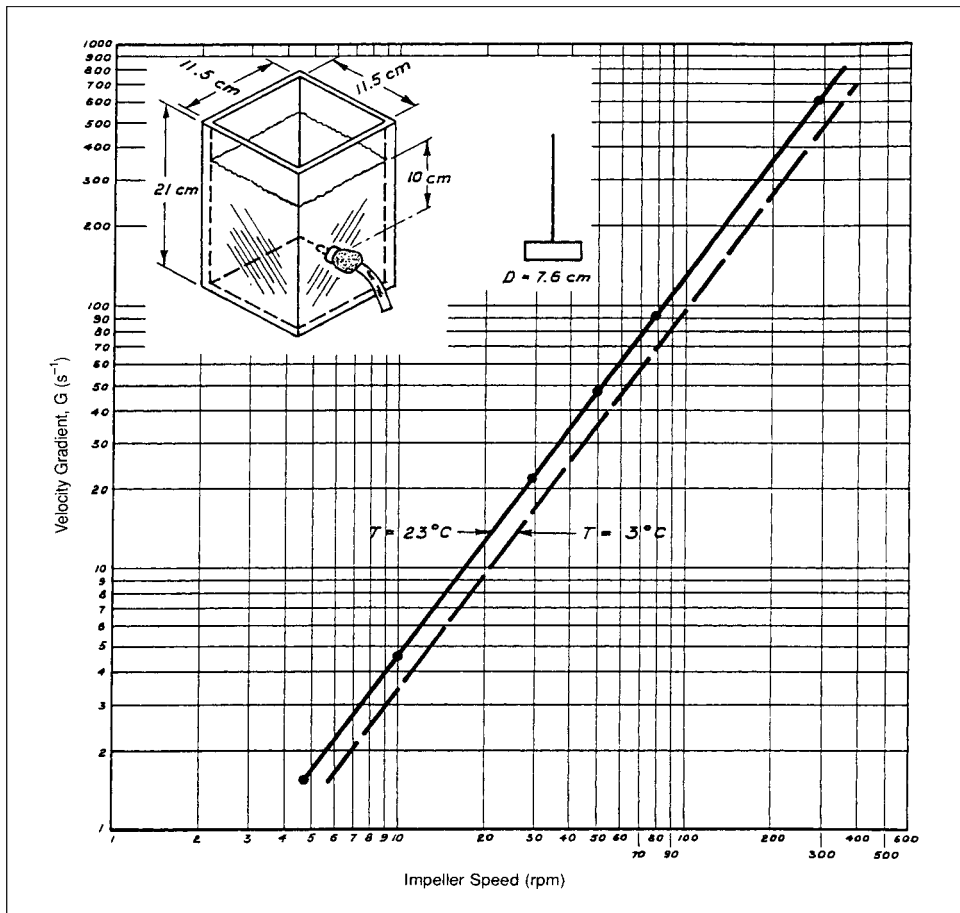


Figure 1. Laboratory G Curve for Flat Paddle in 2 Liter Gator Jar

Appendix M
Chemical Feed Guidelines

Chemical Feed Guidelines

The following guidelines provide information on the use of water treatment chemicals for coagulation and particle removal. Typical chemicals used for these applications include coagulants, flocculants, and filter aids. To use these chemicals properly, it is necessary to understand how the specific chemicals function and the type of calculations that are required to assure accurate feeding. Although these guidelines focus on coagulation and particle removal, the discussion on determining feed rates and preparing feed solutions applies to other water treatment chemical applications such as corrosion and taste and odor control.

Chemicals for Coagulation and Particle Removal

Coagulation Chemicals

Alum

1. Alum (aluminum sulfate) is one of the most widely used coagulants in water treatment. When alum is added to water, insoluble precipitates such as aluminum hydroxide ($\text{Al}(\text{OH})_3$) are formed.
2. The optimum pH range for alum is generally about 5 to 8.
3. Alkalinity is required for the alum reaction to proceed. If insufficient alkalinity is present in the raw water, the pH will be lowered to the point where soluble aluminum ion is formed instead of aluminum hydroxide. Soluble aluminum can cause post flocculation to occur in the plant clearwell and distribution system.
4. As a rule of thumb, about 1.0 mg/L of commercial alum will consume about 0.5 mg/L of alkalinity. At least 5 to 10 mg/L of alkalinity should remain after the reaction to maintain optimum pH.
5. 1.0 mg/L of alkalinity expressed as CaCO_3 is equivalent to:
 - 0.66 mg/L 85% quicklime (CaO)

- 0.78 mg/L 95% hydrated lime ($\text{Ca}(\text{OH})_2$)
 - 0.80 mg/L caustic soda (NaOH)
 - 1.08 mg/L soda ash (Na_2CO_3)
 - 1.52 mg/L sodium bicarbonate (NaHCO_3)
6. If supplemental alkalinity is used it should be added before coagulant addition, and the chemical should be completely dissolved by the time the coagulant is added.
 7. When mixing alum with water to make a feed solution, maintain the pH below 3.5 to prevent hydrolysis from occurring which will reduce the effectiveness of the chemical. A 10 to 20 percent alum solution by weight will maintain this pH requirement in most applications.
 8. Density and solution strength values for commercial alum can be found in Table M-1. A solution strength of 5.4 lb/gal can be used for approximate chemical calculations.

Ferric Chloride

1. The optimum pH range for ferric chloride is 4 to 12.
2. When mixing ferric chloride with water to make a feed solution, maintain the pH below 2.2.
3. Ferric chloride consumes alkalinity at a rate of about 0.75 mg/L alkalinity for every 1 mg/L of ferric chloride.
4. Ferric chloride dosage is typically about half of the dosage required for alum.
5. Density and solution strength values for commercial ferric chloride vary with the supplier. A solution strength of 3.4 lb FeCl_3 /gallon can be used for approximate chemical calculations (i.e., product density of 11.3 lb/gal and 30 percent FeCl_3 by weight).

Table M-1. Densities and Weight Equivalents of Commercial Alum Solutions¹

Specific Gravity	Density lb/gal	% Al₂O₃	Equivalent % Dry Alum²	Strength lb alum/gallon	Strength g alum/liter
1.0069	8.40	0.19	1.12	0.09	11.277
1.0140	8.46	0.39	2.29	0.19	23.221
1.0211	8.52	0.59	3.47	0.30	35.432
1.0284	8.58	0.80	4.71	0.40	48.438
1.0357	8.64	1.01	5.94	0.51	61.521
1.0432	8.70	1.22	7.18	0.62	74.902
1.0507	8.76	1.43	8.41	0.74	88.364
1.0584	8.83	1.64	9.65	0.85	102.136
1.0662	8.89	1.85	10.88	0.97	116.003
1.0741	8.96	2.07	12.18	1.09	130.825
1.0821	9.02	2.28	13.41	1.21	145.110
1.0902	9.09	2.50	14.71	1.34	160.368
1.0985	9.16	2.72	16.00	1.47	175.760
1.1069	9.23	2.93	17.24	1.59	190.830
1.1154	9.30	3.15	18.53	1.72	206.684
1.1240	9.37	3.38	19.88	1.86	223.451
1.1328	9.45	3.60	21.18	2.00	239.927
1.1417	9.52	3.82	22.47	2.14	256.540
1.1508	9.60	4.04	23.76	2.28	273.430
1.1600	9.67	4.27	25.12	2.43	291.392
1.1694	9.57	4.50	26.47	2.58	309.540
1.1789	9.83	4.73	27.82	2.74	327.970
1.1885	9.91	4.96	29.18	2.89	346.804
1.1983	9.99	5.19	30.53	3.05	365.841
1.2083	10.08	5.43	31.94	3.22	385.931
1.2185	10.16	5.67	33.35	3.39	406.370
1.2288	10.25	5.91	34.76	3.56	427.131
1.2393	10.34	6.16	36.24	3.74	449.122
1.2500	10.43	6.42	37.76	3.93	472.000
1.2609	10.52	6.67	39.24	4.12	494.777
1.2719	10.61	6.91	40.65	4.31	517.027
1.2832	10.70	7.16	42.12	4.51	540.484
1.2946	10.80	7.40	43.53	4.71	563.539
1.3063	10.89	7.66	45.06	4.91	588.619
1.3182	10.99	7.92	46.59	5.12	614.149
1.3303	11.09	8.19	48.18	5.34	640.938
1.3426	11.20	8.46	49.76	5.57	668.078
1.3551	11.30	8.74	51.41	5.81	696.657
1.3679	11.41	9.01	53.00	6.05	724.987

¹From Allied Chemical Company "Alum Handbook", modified by adding gm/L dry alum column.

²17% Al₂O₃ in Dry Alum + 0.03% Free Al₂O₃.

Polyaluminum Chloride (1)

1. Polyaluminum chloride (PACl) products are less sensitive to pH and can generally be used over the entire pH range generally found in drinking water treatment (i.e., 4.5 to 9.5).
2. Alum and PACl products are not compatible; a change from feeding alum to PACl requires a complete cleaning of the chemical storage tanks and feed equipment.
3. The basicity of the product determines its most appropriate application:
 - Low basicity PACls (below 20 percent): Applicable for waters high in color and total organic carbon (TOC).
 - Medium basicity PACls (40 to 50 percent): Applicable for cold water, low turbidity, and slightly variable raw water quality.
 - High basicity PACls (above 70 percent): Applicable for waters with highly variable quality, as a water softening coagulant, for direct filtration, and some waters with high color and TOC.
4. Check specific manufacturer's product information for density and strength values.

Polymers (Coagulation)

1. Polymer can be added as either the primary coagulant or as a coagulant aid to partially replace a primary coagulant (e.g., alum).
2. Polymers used for coagulation are typically low molecular weight and positively charged (cationic).
3. The dosage for polymers used for coagulation is dependent on raw water quality.
4. Product density and solution strength information can be obtained from the individual polymer manufacturers.

Flocculation Chemicals

1. Polymers used as flocculants generally have a high molecular weight and have a charge that is positive, negative (anionic), or neutral (nonionic).
2. The purpose of a flocculant is to bridge and enmesh the neutralized particles into larger floc particles, and they are generally fed at a dosage of less than 1 mg/L.
3. Flocculants should be fed at a point of gentle mixing (e.g., diffuser pipe across a flocculation basin) to prevent breaking apart the long-chained organic molecules.
4. Product density and solution strength information can be obtained from the individual polymer manufacturers.

Filter Aid Chemicals

1. Polymers used as filter aids are similar to flocculants in both structure and function.
2. Filter aid polymers are typically fed at dosages less than 0.1 mg/L; otherwise, when fed in excess concentrations they can contribute to filter head loss and short filter run times.
3. Filter aid polymers are fed at a point of gentle mixing (e.g., filter influent trough).
4. Product density and solution strength information can be obtained from the individual polymer manufacturers.

Feeding Chemicals in the Plant

Step 1. Determining the Required Chemical Dosage

1. The appropriate chemical dosage for coagulants is typically determined by lab or pilot scale testing (e.g., jar testing, pilot plant), on-line monitoring (e.g., streaming current meter, particle counter), and historical experience. A guideline on performing jar testing is included in Appendix L.
2. Flocculants are typically fed at concentrations less than 1 mg/L. Jar testing can be used to estimate the optimum dosage.
3. The typical dosage for filter aid polymers is less than 0.1 mg/L. Jar testing, including filtering the samples, is typically not effective for determining

an optimum dose. The polymer manufacturers can provide guidelines on use of their products as filter aids.

Step 2. Determining the Chemical Feed Rate

- Once the chemical dosage is determined, the feed rate can be calculated by the equation below:

$$\text{Feed Rate (lb/day)} = \text{Flow Rate (MGD)} \times \text{Chemical Dose (mg/L)} \times 8.34 \text{ lb/gal}$$

Step 3. Determining the Chemical Feeder Setting

- Once the chemical feed rate is known, this value must be translated into a chemical feeder setting. The approach for determining the setting depends on whether the chemical is in a dry or liquid form.
- For dry chemicals, a calibration curve should be developed for all feeders that are used in the plant. A typical calibration curve is shown in Figure M-1. The points on the curve are determined by operating the feeder at a full operating range of settings and collecting a sample of the chemical over a timed period for each setting. Once the sample weight is determined by a balance, the feed rate can be determined for that set point. For example, the feed rate for the 100 setting was determined by collecting a feeder output sample over a 2-minute period. The sample weight was 5.8 lb. The associated feed rate can then be converted into an equivalent hourly feed rate as follows:

$$\text{Feed Rate} = \frac{5.8 \text{ lb}}{2 \text{ min}} \times \frac{60 \text{ min}}{\text{hr}} = \frac{174 \text{ lb}}{\text{hr}}$$

- For liquid chemicals, a calibration curve should also be developed for all liquid feeders used in a plant. An approach similar to dry feeder calibration is followed; however, a volumetric cylinder is typically used to collect the sample. For example, 50 mL of liquid chemical collected

over 2 minutes would equate to a feed rate of 25 mL/min. A graph similar to Figure M-1 can be developed showing pump setting (e.g., % speed) versus feed rate in mL/min.

- For liquid chemicals, an additional step is necessary to convert the required weight-based feed rate to a volume-based pumping rate. The following equation can be used to determine the pumping rate:

$$\text{Pump Rate (mL/min)} = \frac{(F_R) \text{ lb}}{\text{day}} \times \frac{\text{gal}}{(C_S) \text{ lb}} \times \frac{\text{day}}{1,440 \text{ min}} \times \frac{3,785 \text{ mL}}{\text{gal}}$$

F_R = Feed Rate (lb/day)

C_S = Chemical Strength (lb/gal)

Preparation of Feed Solutions

Liquid solutions of both dry and liquid chemicals are frequently prepared in a plant to prepare the chemical for feeding (e.g., activating polymer) and to allow the feeding of the chemical in an efficient manner. Two examples are presented below to describe approaches for preparing chemical solutions from dry and liquid chemicals.

Preparation of an Alum Feed Solution

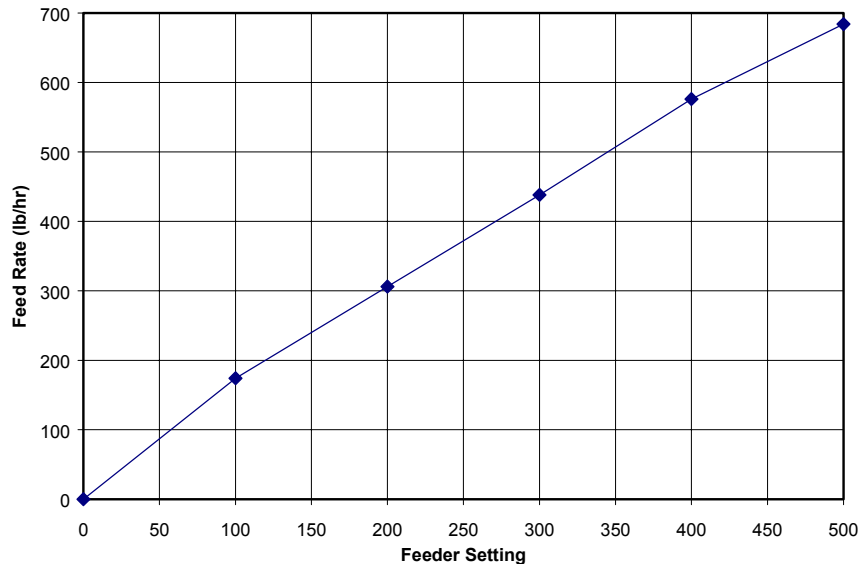
- Determine the desired percent solution for feeding the alum. As described under the previous alum discussion, a percent solution of 10 to 20 percent is typically used. In this example, assume a 15 percent solution.
- Based on the volume of alum solution to be prepared, determine the weight of alum to add to the solution tank. For an alum solution volume of 500 gallons, determine the alum weight as follows:

$$\text{Alum Weight} = 500 \text{ gal} \times \frac{8.34 \text{ lb}}{\text{gal}} \times 0.15 = 625 \text{ lb}$$

Figure M-1. Example dry chemical feeder calibration chart.

Setting	Sample Wt. (lb)	Time (minutes)	Feed Rate (lb/hr)
0	0	0	0

100	5.8	2.0	174
200	5.1	1.0	306
300	7.3	1.0	438
400	4.8	0.5	576
500	5.7	0.5	684



3. Determine the alum strength (A_s) for use in calculating feed rates. The alum strength for the example above is calculated as follows:

$$\text{Alum Strength } (A_s) = \frac{625 \text{ lb}}{500 \text{ gal}} = \frac{1.25 \text{ lb}}{\text{gal}}$$

Preparation of a Polymer Feed Solution

1. Polymer manufacturers provide guidelines on preparation of their products, including whether the product is fed neat (i.e., undiluted) or in a diluted form. Diluted polymers are typically mixed at 2% by weight or less; otherwise, they become difficult to mix effectively. For this example, assume a 1% solution is to be prepared.
2. Based on the volume of solution to be prepared, determine the weight of polymer to add to the solution tank. For a solution volume of 200 gallons, determine the polymer weight as follows:

$$\text{Polymer Weight} = 200 \text{ gal} \times \frac{8.34 \text{ lb}}{\text{gal}} \times 0.01 = 16.7 \text{ lb}$$

3. It is frequently easier to measure polymer volumetrically rather than by weight, so the weight of polymer can be converted to an equivalent volume by obtaining the product density from the manufacturer. For example, if the polymer density is 9.5 lb/gal, the volume is calculated as follows:

$$\text{Polymer Volume} = 16.7 \text{ lb} \times \frac{\text{gal}}{9.5 \text{ lb}} = 1.76 \text{ gal}$$

4. Determine the polymer strength (P_s) for use in calculating feed rates. The polymer strength for the example above is calculated as follows:

$$\text{Polymer Strength } (P_s) = \frac{16.7 \text{ lb}}{200 \text{ gal}} = \frac{0.0835 \text{ lb}}{\text{gal}}$$

References

-
1. Lind, Chris. 1996. "Top 10 Questions about Alum and PACI." *Opflow*, 22(8):7. AWWA, Denver, CO.

Appendix N
Conversion Chart

Conversion Chart

English Unit	Multiplier	SI Unit
acre	0.405	ha
acre-ft	1,233.5	cu m
cfs	1.7	cu m/min
cu ft	0.0283	cu m
cu ft	28.32	l
°F	$5/9 \times (°F - 32)$	°C
ft	0.3048	m
ft/sec	30.48	cm/sec
gal	3.785	l
gpm	0.0631	liter/sec
gpm	8.021	cu ft/hr
gpd/sq ft	0.0408	cu m/day/sq m
gpm/sq ft	40.7	l/min/sq m
inch	2.54	cm
lb	0.454	kg
lb	454	g
MGD	3,785	cu m/day
psi	0.070	kg/sq cm
sq ft	0.0929	sq m